Coastal Altimetry

A European Space Agency perspective

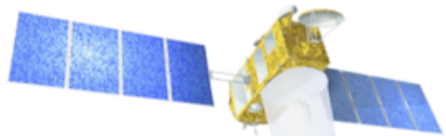
Craig Donlon

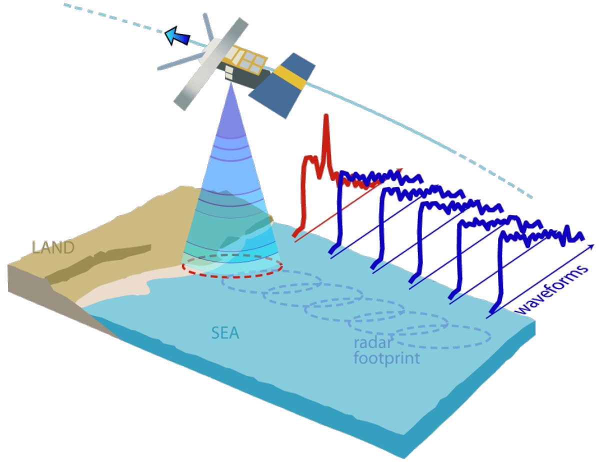
ESA/ESTEC, Noordwijk, the Netherlands

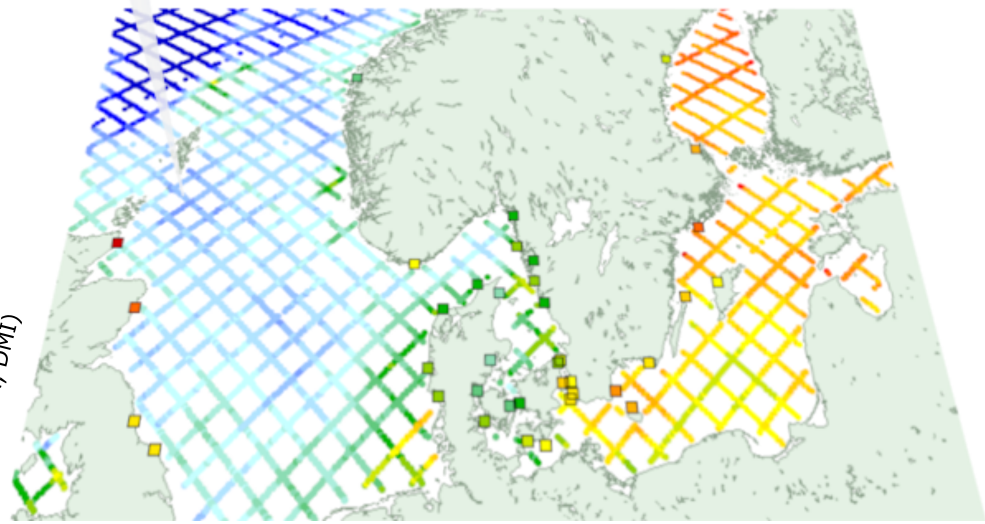
Thanks to J. Benveniste, P. Harwood, P. Cipollini, K. Madsen

Outline

- Historical Context
- Climate Change Initiative (CCI) Sea Level
- Coastal Altimetry @ESA
- Data User Element (DUE) eSurge
- Future perspectives: Sentinel-3 and Sentinel-6
- Summary





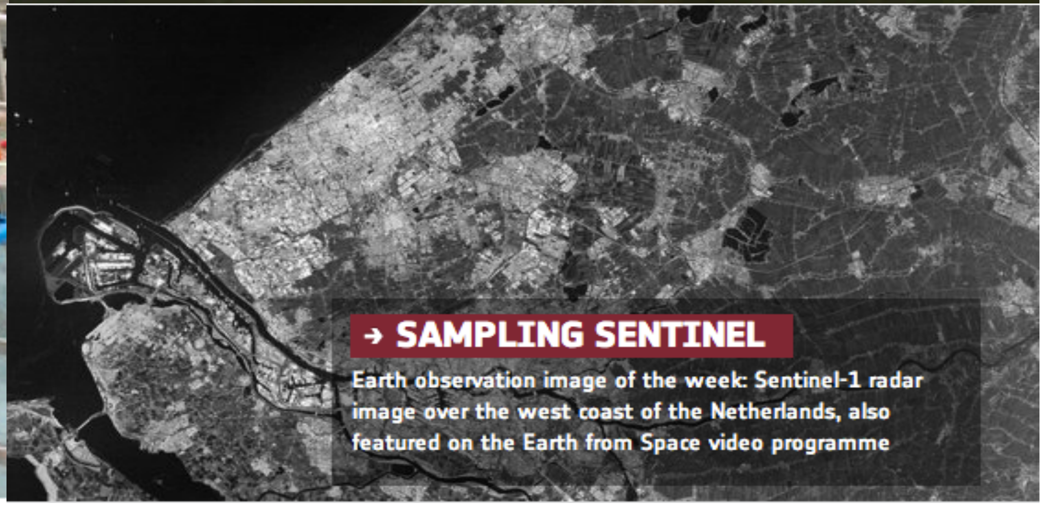


(K Masden, DMI)

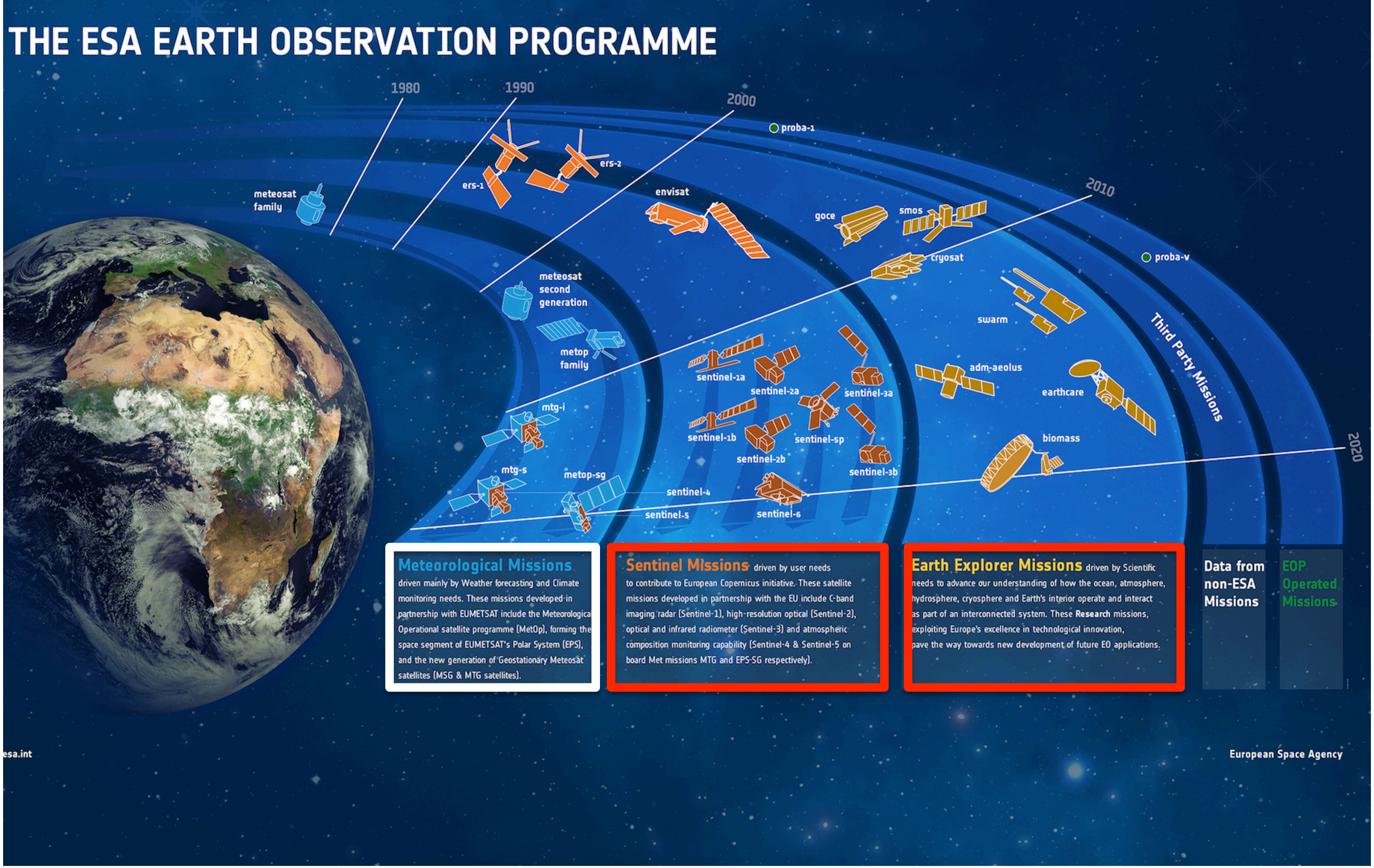

24

esa sentinel-1

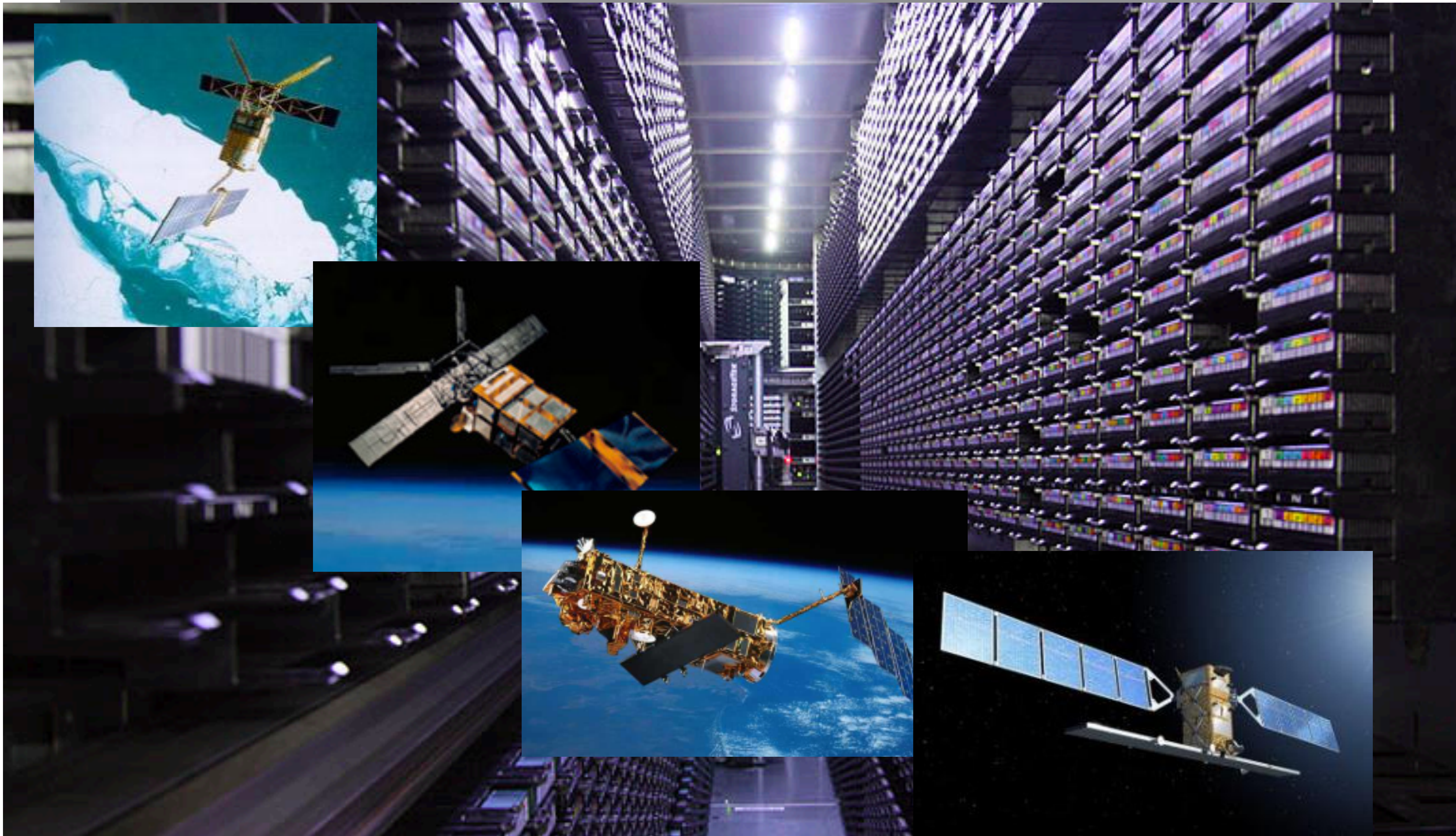
3rd April 2014



Three Pillars of ESA Earth Observation

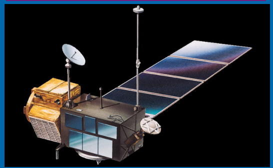


EO Assets & Capabilities
Long term Climate Data Archives



Satellite Altimetry Instruments/Missions

Reference Orbit Missions

Poseidon-1

1992
TOPEX/
Poseidon

Poseidon-2

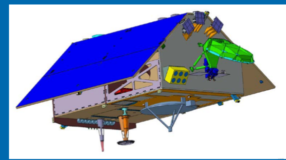
2001
JASON-1

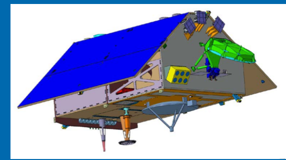
Poseidon-3

2008
JASON-2

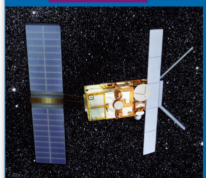
Poseidon-3

2015
JASON-3

Poseidon-4

2020
S6/J-CS A

Poseidon-4

2026
S6/J-CS B

Polar Orbit Missions

RA

1992
ERS-1

RA

1995
ERS-2

RA-2

2002
ENVISAT

SIRAL

2005
CS-1

SIRAL

2010
CS-2

SARAL

2012
AltiKa

SRAL

2015
S3-A

SRAL

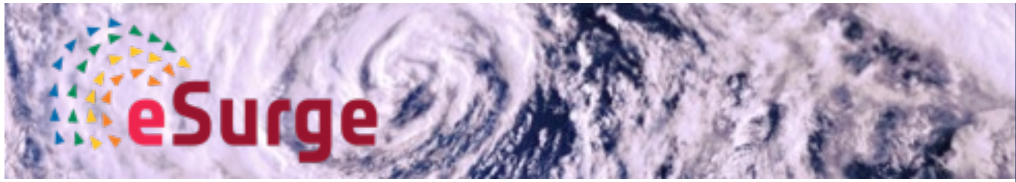
2017
S3-B

SRAL

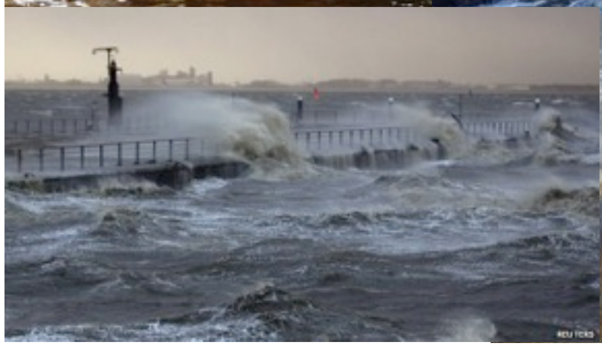
2023
S3-C

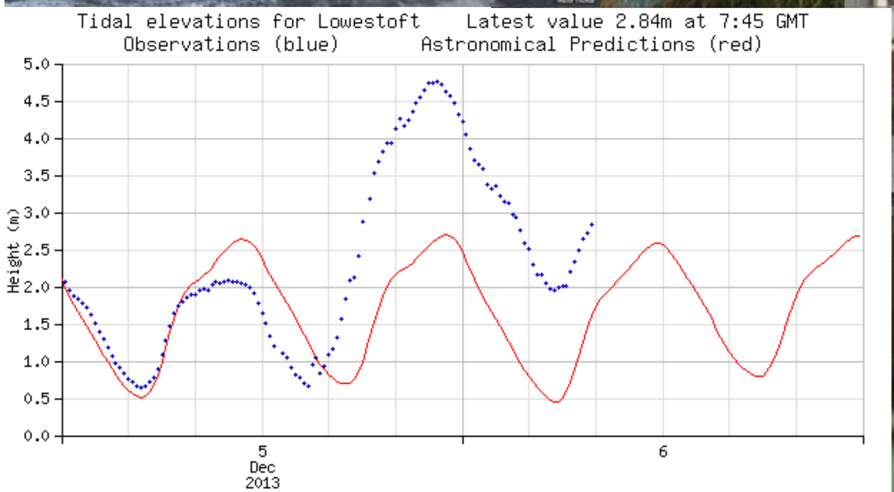
SRAL

2026
S3-D

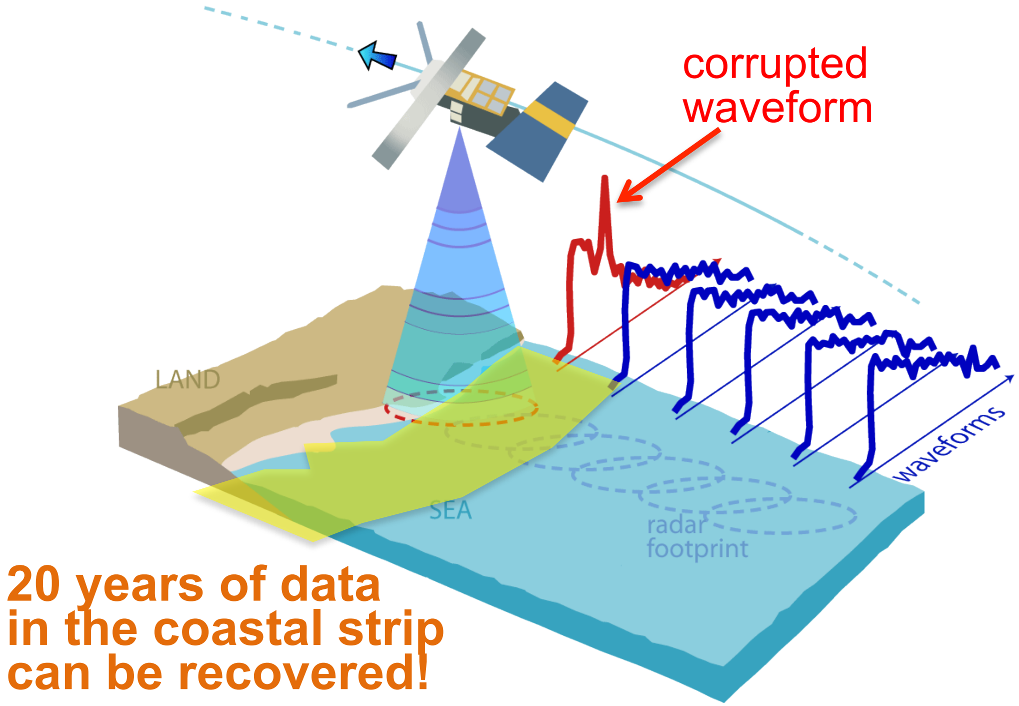


UK Winter 2013/2014.





A new frontier for Altimetry.
(P.Cippolini, eSurge)



Traditionally, data in the **coastal zone** are flagged as bad and left unused

(coastal zone: as a rule of thumb 0-50 km from coastline, but in practice, **any place where standard altimetry gets into trouble** as waveforms are non-Brown and/or corrections become inaccurate)

In recent years a vibrant community of researchers has started to believe that most of those coastal data can be recovered

Also important for **SAR & Ka-band altimetry, having good coastal performance - and for coastal wave field**

Coastal Altimetry @ESA

- **Some early studies**
  - Manzella et al. 1997 – custom wet tropospheric correction
  - Crout 1998 - could recover data when coastal topography is flat
  - Anzenhofer et al. 1999 – retracking coastal waveforms
  - Vignudelli et al. 2000 - Signal recovered consistent with in situ data

ALBICOCCA
France-Italy-UK 2001/04
Feasibility

ALTICORE-EU
EU/INTAS 2006/08
Capacity building

ALTICORE-India
ALTICORE-Africa

MAP/XTRACK/MARINA
CNES/LEGOS/**CTOH**, ongoing
Integrated approach to data editing & filtering, multimission, dissemination

DATA available

PRODUCT DEVELOPMENT STUDIES INCLUDING WAVEFORM RETRACKING

PISTACH
CNES 2007-present
For Jason-2

COASTALT
ESA 2008-2012
For Envisat

→ now following with **eSurge**
(*multimission, 2011-2014*)

...plus several Projects funded by NASA, CNES, ESA...


esa
coastal altimetry workshop series
Introduction
Themes
Programme
Registration & Deadlines
Authors Instructions
Committees
Contact
COASTALT
Latest News
CAW-9: 18-19 Oct 2015 US East Coast
Workshop on Altimetry for Regional and Coastal Ocean Models
Stefano Vignudelli gets PORSEC Distinguished Science Award
Presentations and posters from CAW-8 are online
Another great "Council" of the coastal altimetry community
more
Home
The COASTALT Project
Cryosat+ Oceans: CP4O project pages
CP4O Home
Team
Presentations
Deliverables
Data
Planning
Meetings
CCN
Contact
CP4O (Cryosat Plus For Oceans)
News:
Validation Data Products available to download and evaluate (data pages)
New Online and On Demand CryoSat-2 SAR FBR data processing service (data pages)
Final Review Meeting 1-2 July, ESRIN, Frascati (meetings pages)
Introduction:
CP4O is a project funded under the ESA STSE (Support To Science Element) Programme to develop and evaluate ocean products from Cryosat-2 data. CNES are also providing funding to support CLS participation.
The general objectives of the "Cryosat Plus for Oceans" (CP4O) project are:
to build a sound scientific basis for new scientific and operational applications of Cryosat-2 data over the open ocean, polar ocean, coastal seas and for sea-floor mapping.
to generate and evaluate new methods and products that will enable the full exploitation of the capabilities of the Cryosat-2 SIRAL altimeter, and extend their application beyond the initial mission objectives.
to ensure that the scientific return of the Cryosat-2 mission is maximised.
Click here for a CP4O project brochure
In addition there are specific objectives under each of the four sub-themes as follows:
Theme 1: Open Ocean Altimetry
S. Vignudelli
A. Kostianoy
P. Cipollini
J. Benveniste
(Eds.)
cnes
esa
Coastal Altimetry
WWW.COASTALALTIMETRY.ORG
WWW.COASTALT.EU
Copyright © European Space Agency. All rights reserved.

ESA Climate Change Initiative (CCI)

esa

CCI PROGRAM

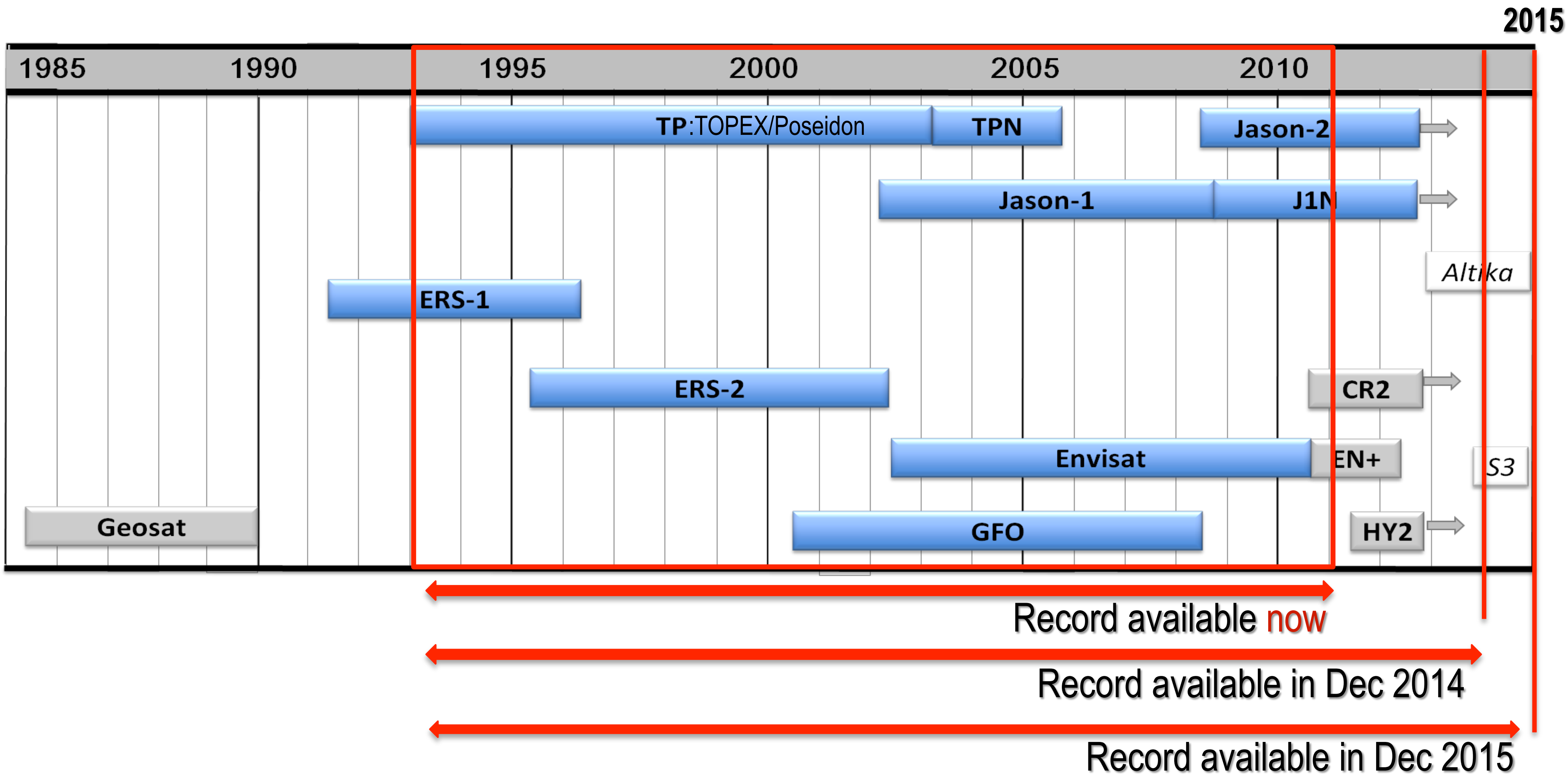
esa
European Space Agency

aerosol cci
ozone cci
ocean colour cci
cloud cci
sea ice cci
land cover cci
fire cci
cmug cci
sea level cci
sst cci
ghg cci
glaciers cci
soil moisture cci
ice sheets cci

Objective: To realise the best long term ECVs records the full potential of the long-term global Earth Observation archives from satellites (not just ESA but all sources via international collaboration) as a significant and timely contribution to the ECV databases required by UNFCCC.

What is in the CCI-sea level product?

Based on satellite data from ESA, CNES, EUMETSAT, NASA, NOAA, US NAVY, ISRO



CCI product: same approach as AVISO with standards tuned to climate

Level 0: Data acquisition

Level 1: Raw telemetry

Level 2: Altimetry data
1) instrumental errors
2) atmospheric propagation and perturbations
3) Geophysical corrections
4) POD

Same stand…
when …

…try data

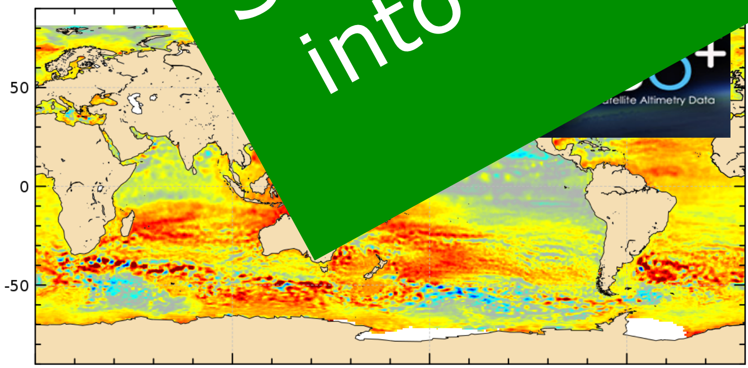
…nd perturbations

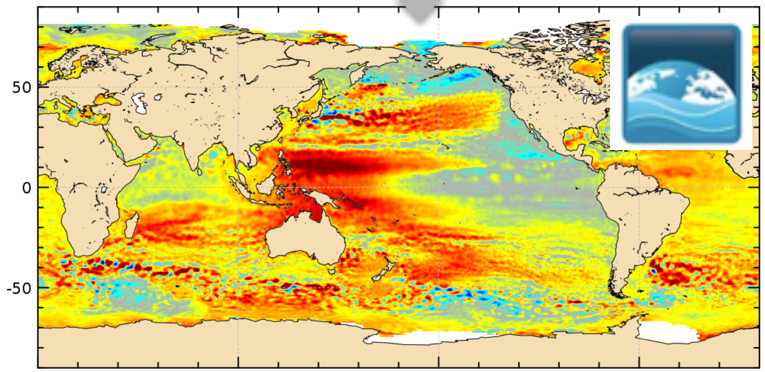
Level 3: Cross calibratio…
Validation

Level 4: …

Level 4: Final products

Sea Level CCI wil be extended into the Coastal Zone during Phase-II



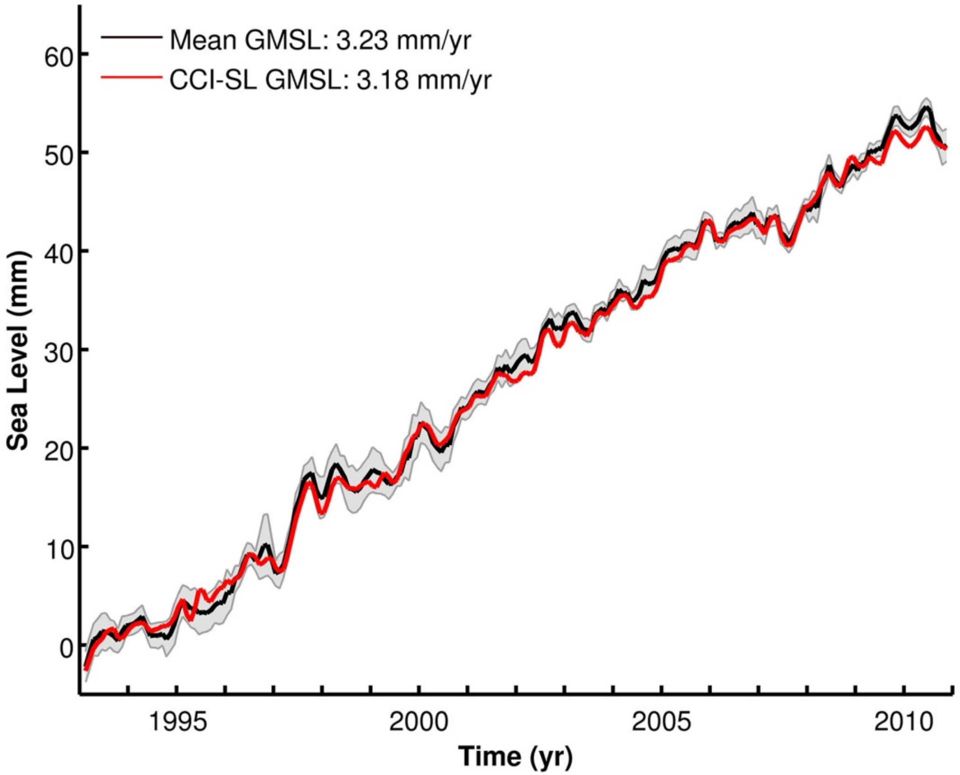


Objective: get the best long-term trends and decadal variability possible.

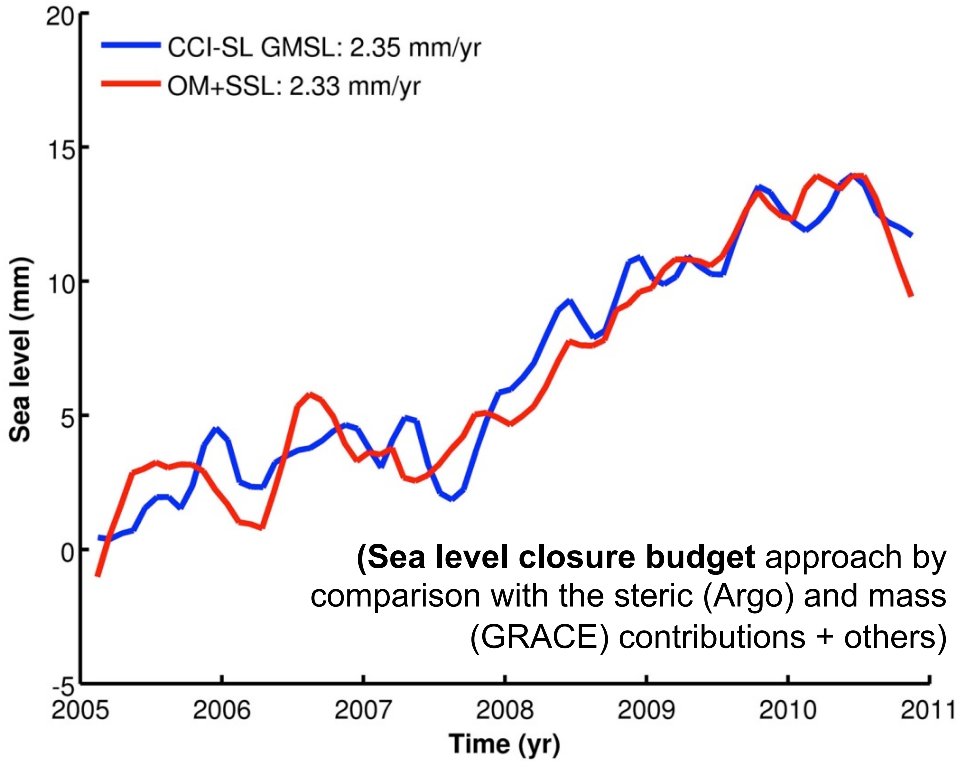
Improvements of the sea level record for climate studies: Validation

CCI Global mean sea level

Global mean sea level (average of AVISO, Colorado University, NOAA and GSFC data)



Global mean sea level trend



Comparison with GRACE+ARGO

ESA Sea_Level_cci: Uncertainties

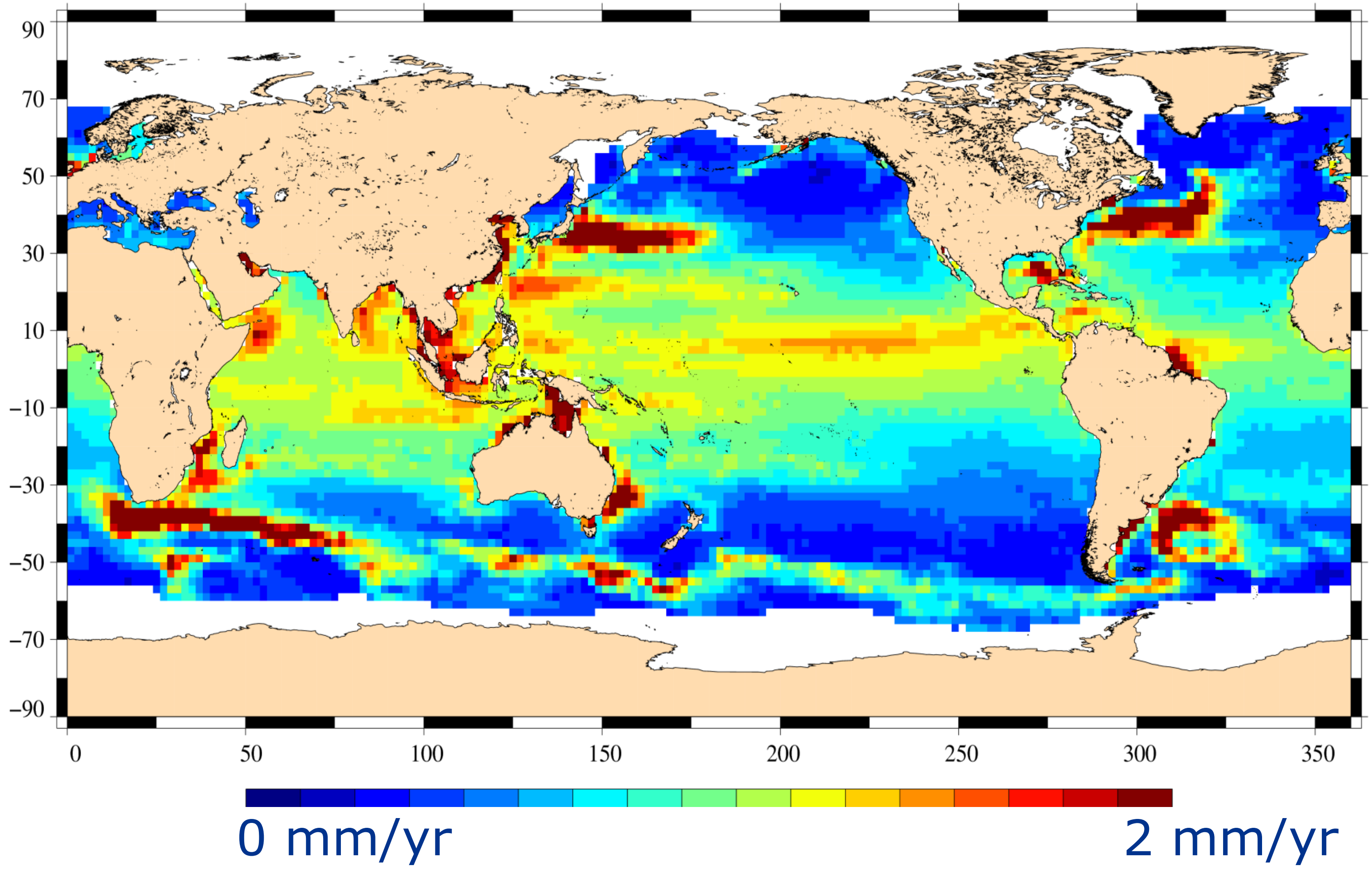
Uncertainties (Ablain et al, 2012)

Spatial Scales	Temporal Scales	GCOS* Requirements	CCI product errors
Global Mean Sea Level (10-day averaging)	Long-term evolution (> 10 years)	0.3 mm/yr	< 0.5 mm/yr
	Inter annual signals (< 5 years)	0.5 mm over 1 year	< 2 mm over 1 year
	Periodic signals (Annual, 60-days,…)	Not defined	Annual < 1 mm 60-day < 5 mm
Regional Mean Sea Level (2x2 deg boxes and 10-day averaging)	Long-term evolution (trend)	1 mm/yr	< 3 mm/yr
	Inter annual signals (> 1 year)	Not Defined	Not evaluated
	Periodic signals (Annual, 60-days,…)	Not Defined	Annual < 5mm 60-day < 10 mm

** More details to the satellite-based component of the "Implementation Plan for the Global Observing System for Climate in Support of the UNFCCC (2010 Update)" GCOS-154, December 2011)*

Sea-level error characterisation

• Information requested by users or climate modellers: Provide regional sea level trend error maps ➡ Phase 2 on-going work



Sea Level ECV products

- **For the 2016 reprocessing (V2.0), several improvements are foreseen** :

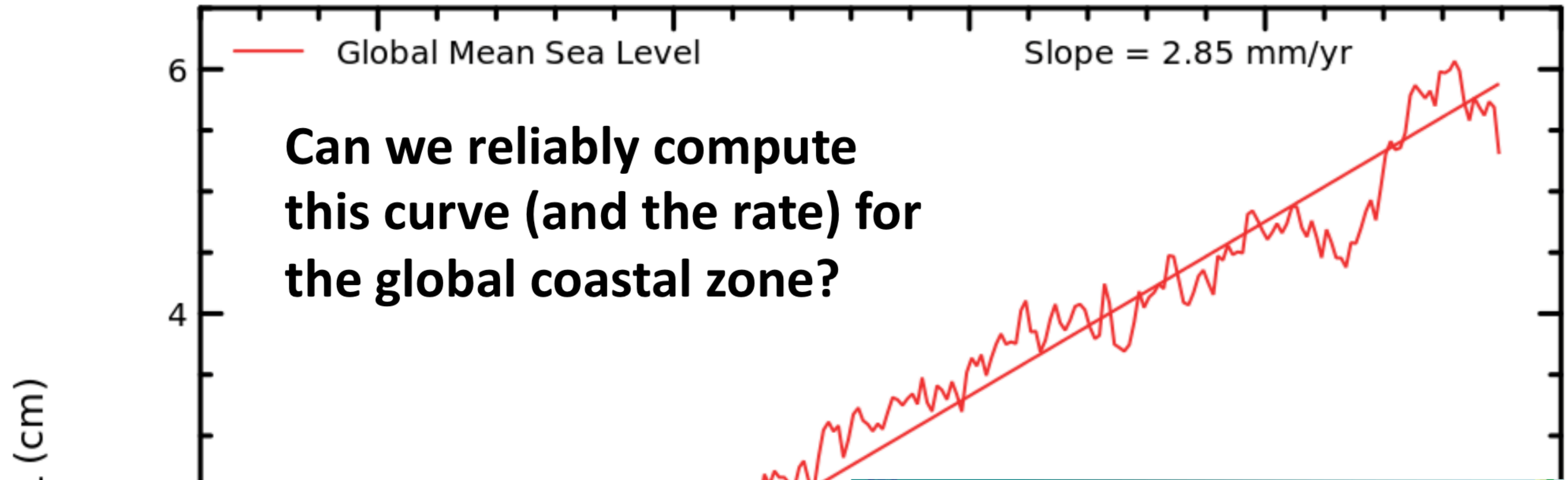
⇒ Integration of new altimeter missions: Cryosat-2 (April 2010), SARAL/Altika (February 2013), Sentinel-3 (late 2015) and Jason-3 (mid 2015)

⇒ Development, evaluation and selection of new sea level corrections and algorithms in order to have state of the art consistent 'climate' standards: use of new atmospheric reanalyses, new orbit solutions, new ocean tidal models, …

⇒ Improvement of sea level calculation in Arctic ocean : increase data coverage near-by and under sea-ice

⇒ **Improvement of sea level calculation in coastal areas**

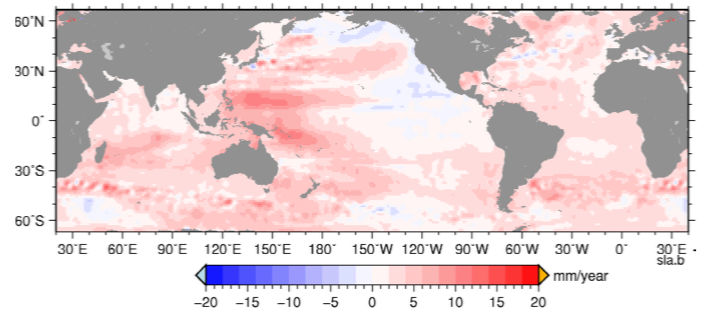
Can we reliably compute this curve (and the rate) for the global coastal zone?



Conclusion?

- Is sea level rise (significantly) larger near the coast?
  - NO
  - But it isn't smaller either!
  - And was it really useful to ask the question in the first place?
  - Don't we have to worry most about places with a lot of people living near a shallow coast?

Scharroo, CAW-3, 2009

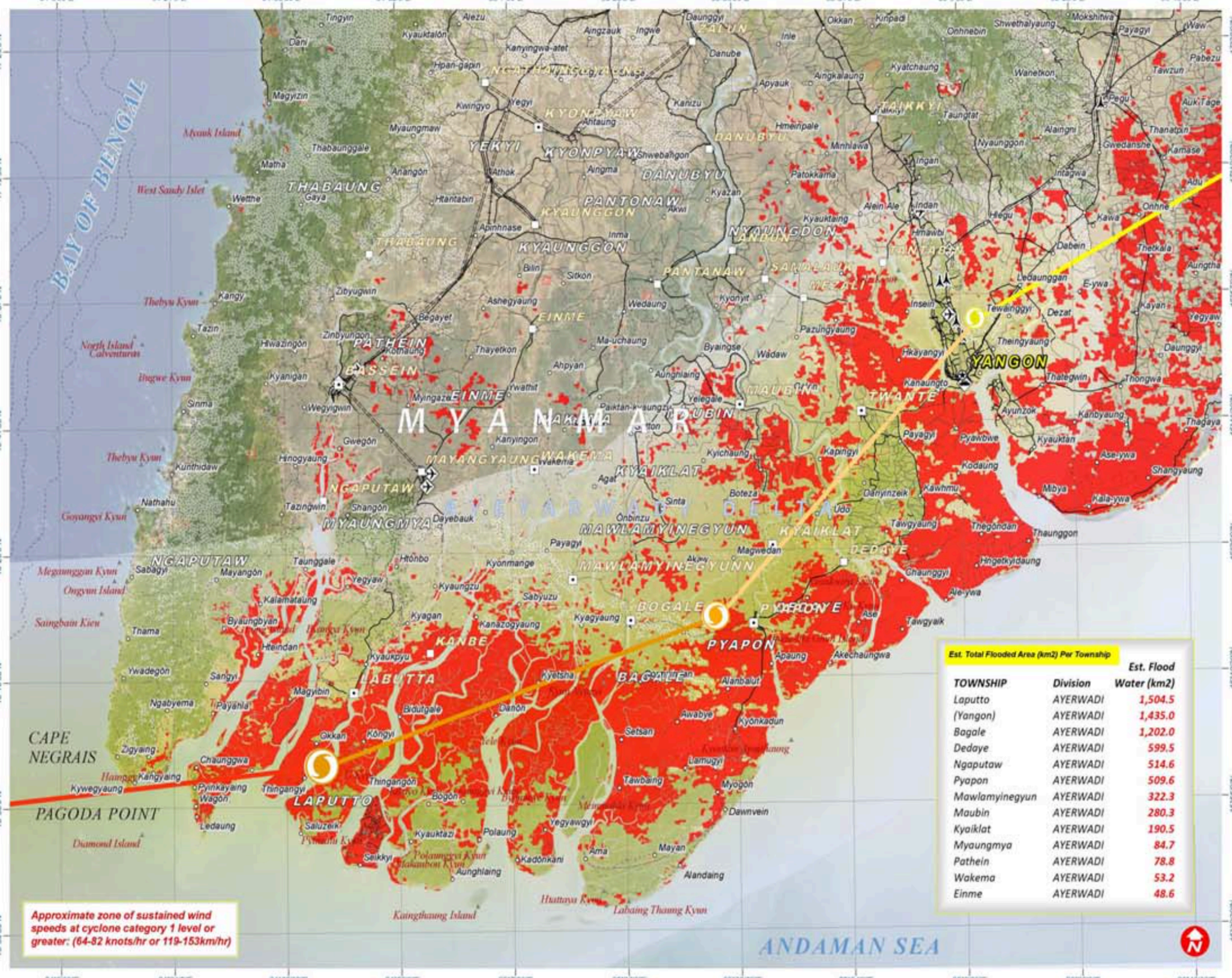


FLOOD ASSESSMENT FOR CYCLONE NARGIS AFFECTED AYEYARWADY DIVISION, MYANMAR

Flood Analysis with MODIS Terra & Aqua Data Recorded 5 May & 15 April 2008

This map illustrates satellite-detected flood waters over the affected Ayeyarwady Division, Myanmar as of 5 May 2008. Red areas shown in the map represent standing flood waters identified from MODIS satellite imagery acquired on 5 May 2008 at a spatial resolution of 250m. Flooded area estimates by township have been calculated in km2. Please note: township data is incomplete in coverage. This flood detection is a preliminary analysis & has not yet been validated in the field.

Cyclone Nargis — 5 May 2008 — *Version 1.1* — TC-2008-000057-MMR



Est. Total Flooded Area (km2) Per Township

TOWNSHIP	Division	Est. Flood Water (km2)
Laputto	AYERWADI	1,504.5
(Yangon)	AYERWADI	1,435.0
Bogale	AYERWADI	1,202.0
Dedaye	AYERWADI	599.5
Ngaputaw	AYERWADI	514.6
Pyapon	AYERWADI	509.6
Mawlamyinegyun	AYERWADI	322.3
Maubin	AYERWADI	280.3
Kyaiklat	AYERWADI	190.5
Myaungmya	AYERWADI	84.7
Pathein	AYERWADI	78.8
Wakema	AYERWADI	53.2
Einme	AYERWADI	48.6

Legend

Capital · City / Large Town · Town · Village · Airfield · Port · International Border · Main Road · Secondary Road · Track / Trail · Railroad · Utility Line · Tower

EST. CYCLONE NARGIS TRACK & WIND SPEED:

CATEGORY: TS 34-63 knots/hr · 1 64-82 knots/hr · 2 83-95 knots/hr · 3 93-113kts/hr · 4 114-135kts/hr

Approximate zone of sustained wind speeds at cyclone category 1 level (64-82 knots/hr or 119-153km/hr)

SATELLITE FLOOD ANALYSIS

Satellite-Detected Flood Waters (5 May 2008)

Clouds (not assessed) (5 May 2008)

Map Scale for A3: 1:900,000

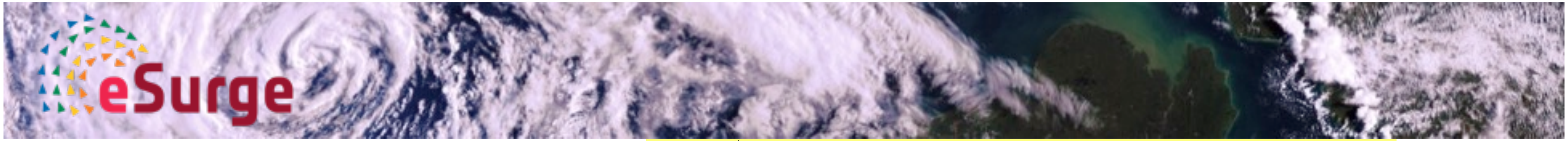
0 5 10 20 30 40 Kilometers

- Cyclone Data .... NOAA, Uni of Hawai'i, Tropical Storm Risk
- GIS Data .... USGS, NGA, ESRI, Respond/Keyobs
- Satellite Data .... MODIS-Aqua & Terra
- Imagery Date .... 5 May & 15 April 2008
- Resolution 250m
- Map Production .... UNOSAT (5 May 2008)
- Projection .... UTM Zone 46 North
- Datum .... WGS 1984

The depiction and use of boundaries, geographic names and related data shown here are not warranted to be error-free nor do they imply official endorsement or acceptance by the United Nations. This map was produced by the United Nations Institute for Training and Research (UNITAR) Operational Satellite Applications Program (UNOSAT). UNOSAT provides satellite imagery & related geographic information to UN humanitarian & development agencies & their implementing partners.

UNOSAT satellite solutions for all

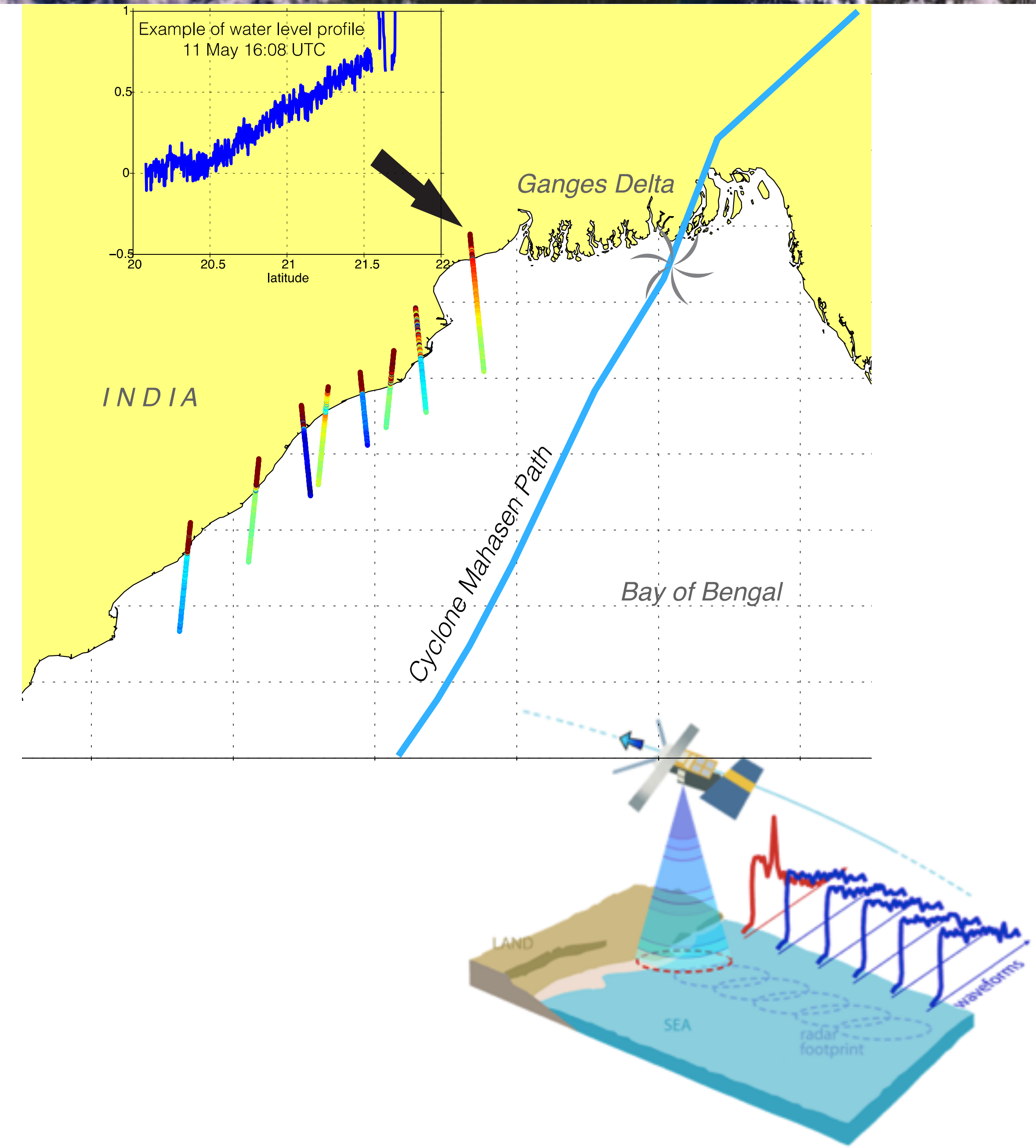
Contact Information: info@unosat.org
24/7 Hotline: +41 76 487 4998
www.unosat.org



Coastal Altimetry

Data can help where there are no in-situ measurements available.
"Virtual Tide Gauges"

Even where tide gauges are available, altimetry can improve the accuracy of numerical models, e.g. giving extra values for ensemble pruning.

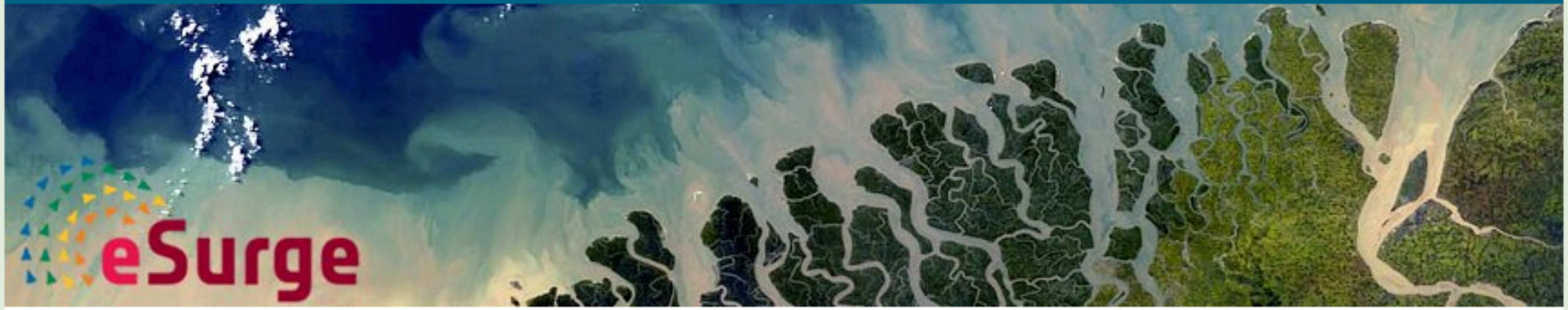


due http://www.storm-surge.info/

data user element

esa

Home | Data Access | Storm Surges | Case Studies | Training | Further Reading | Get Involved | About eSurge | Contact Us



Data Access

Click here to view data for surge events.

Project News

Sentinel-3 for Science Workshop, Venice, Italy, 2-5 June 2015.
Tuesday 20th January 2015

Programme for symposium "Towards a NRT Storm Surge Core Service" now online
Friday 9th January 2015

Satellite data are currently being made available for the following live events, for which a storm surge is anticipated or has recently occurred:

eSurge LIVE

- **OLWYN-15** (North-East Australia, 11 Mar 2015):
  More information or access data.
- **NATHAN-15** (North-East Australia, 10 Mar 2015):
  More information or access data.

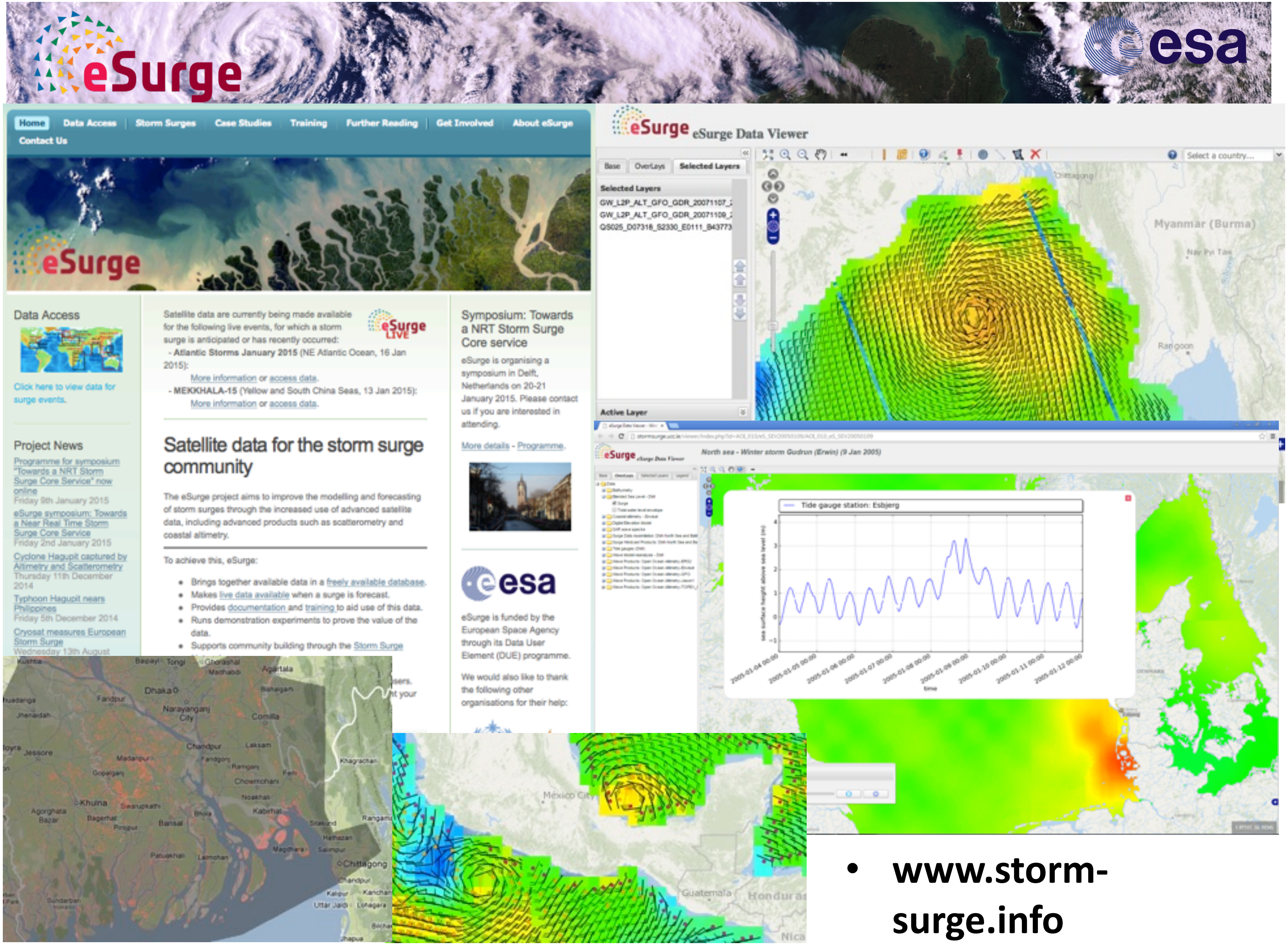
Satellite data for the storm surge community

The eSurge project aims to improve the modelling and forecasting of storm surges through the increased use of advanced satellite data, including advanced products such as scatterometry and coastal altimetry.

Delft Symposium

Thanks to everyone who attended our symposium in Delft. Reports from this event are now online.

esa



- **www.storm-surge.info**

Coastal altimetry processing

Setup a **multimission processing chain** from L1b to L2, generating specialized surge products (TWLE).

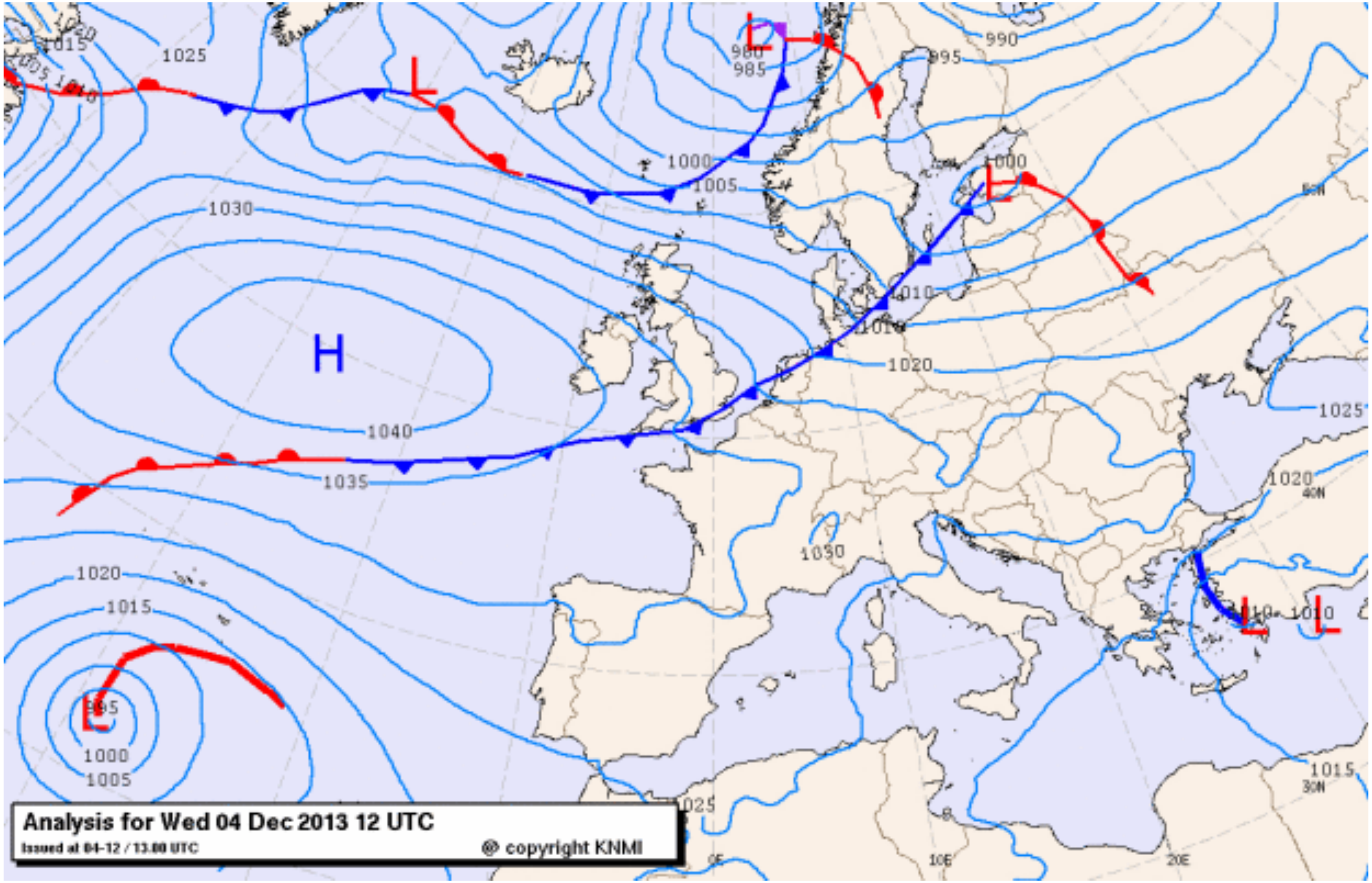
Demonstrated this processor in Near-Real-Time for Cryosat-2 data and on Interim GDR for Jason-2 data (notable examples for Xaver, Hagupit & Jan 2015 North Sea Storm).

Developed, implemented, validated (and fully published) a new retracking algorithm (ALES) that outperforms standard processing in the coastal zone and can be used over the open ocean too, being just marginally sub-optimal there (avoiding discontinuities that usually arise when 'switching' algorithms at some points along-track).

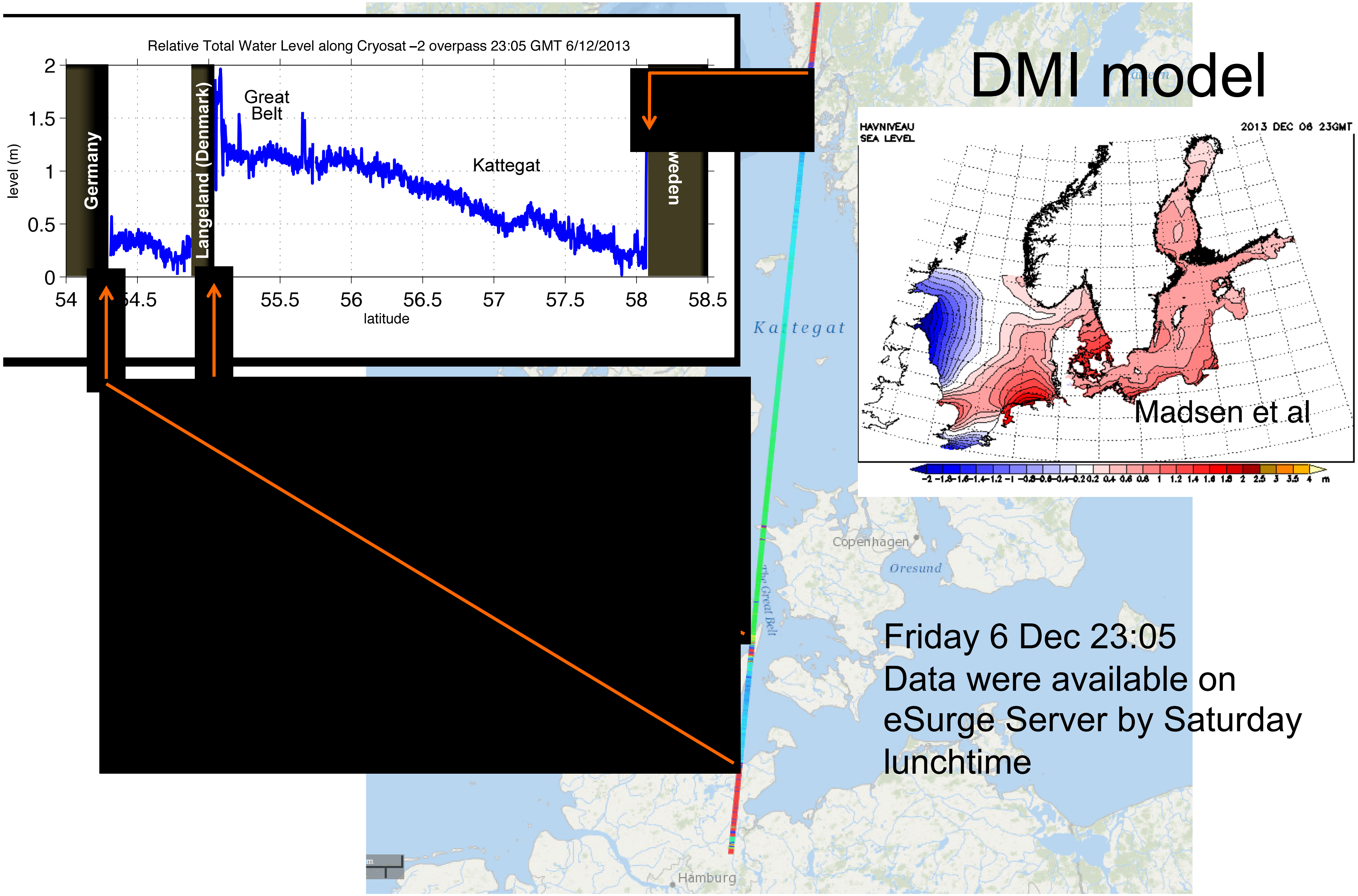
- Passaro, Cipollini et al Rem Sens Env 2014
- Passaro, Fenoglio, Cipollini, IEEE TGARS 2015
- Passaro, Cipollini, Benveniste, JGR, under review

eSurge esa

NRT – Xaver/Bodil, 5/6 Dec 2013

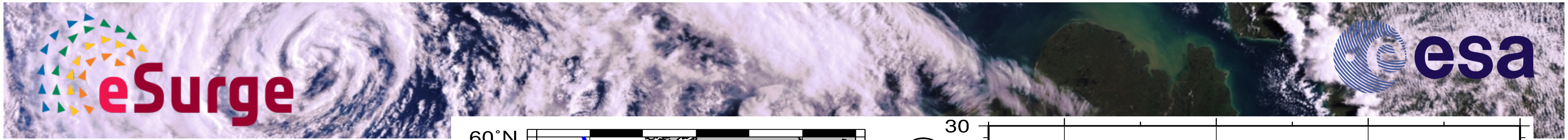


SAR in NRT for Xaver – Dec '13

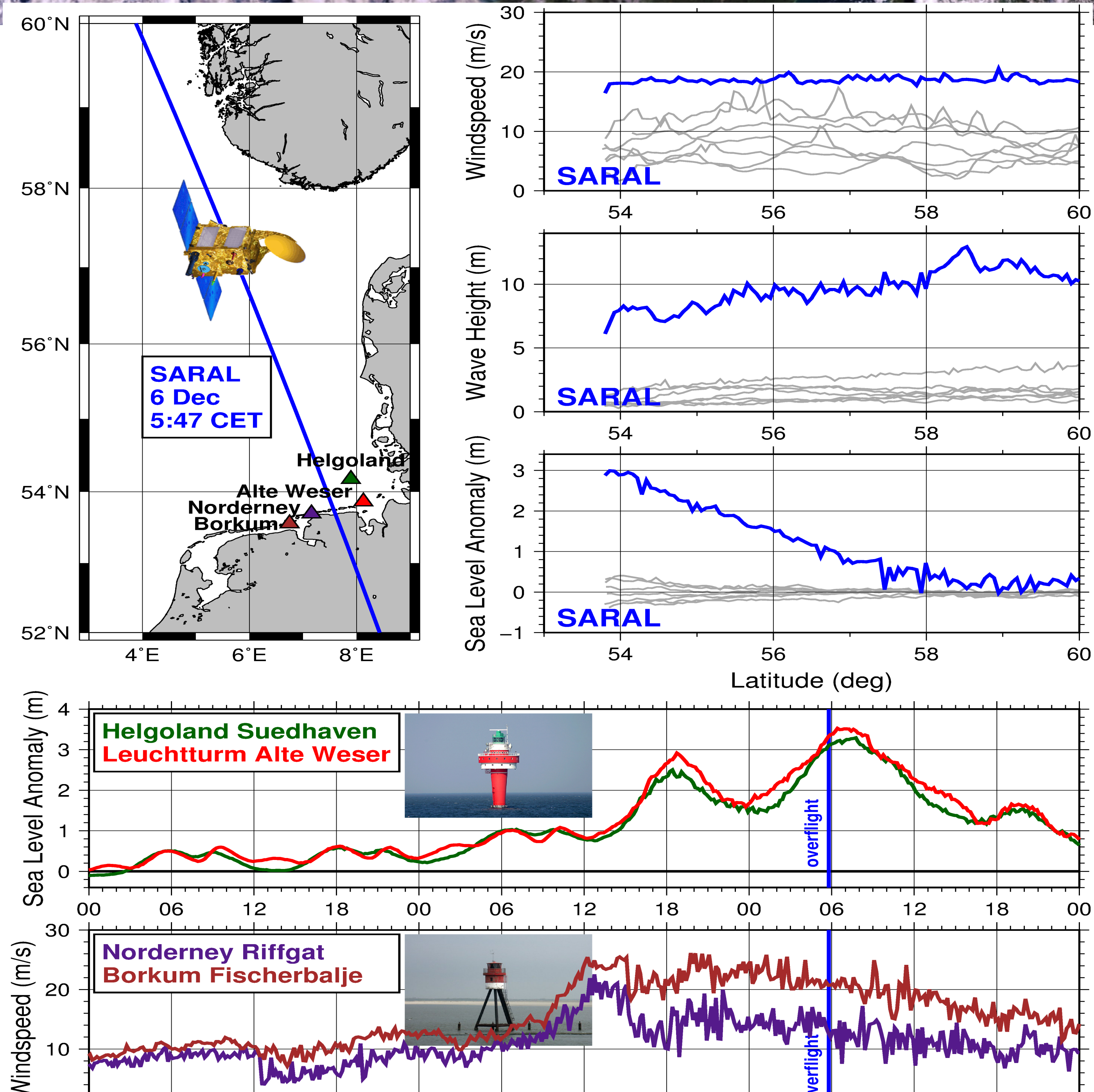


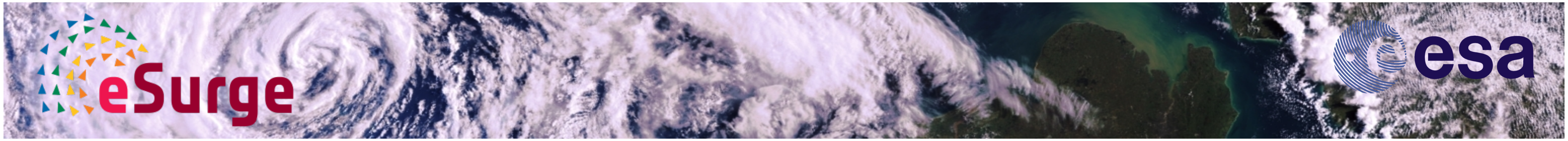
DMI model

Friday 6 Dec 23:05
Data were available on eSurge Server by Saturday lunchtime

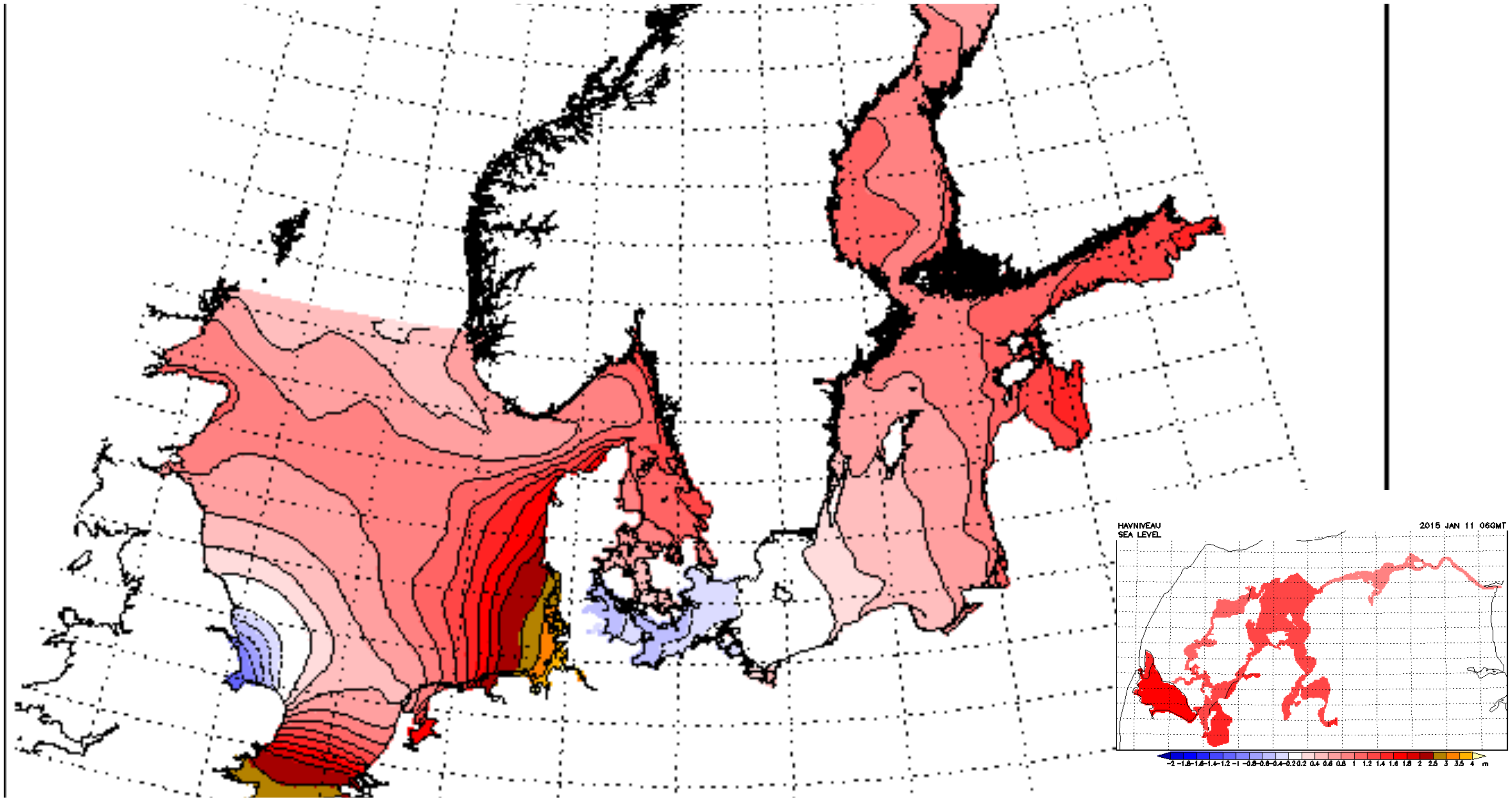


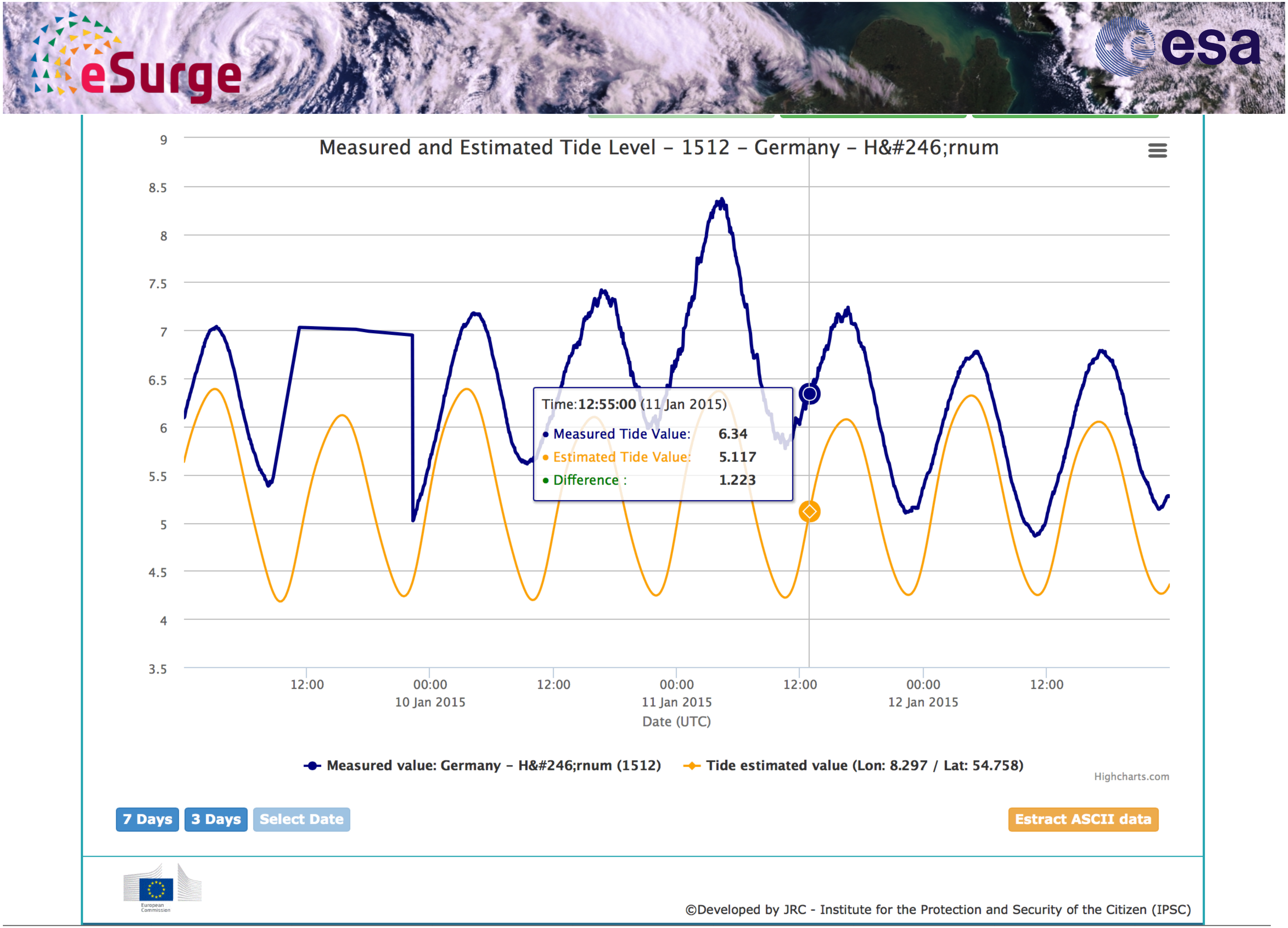
Fenoglio et al., 2014
(also presented at
CAW-8)





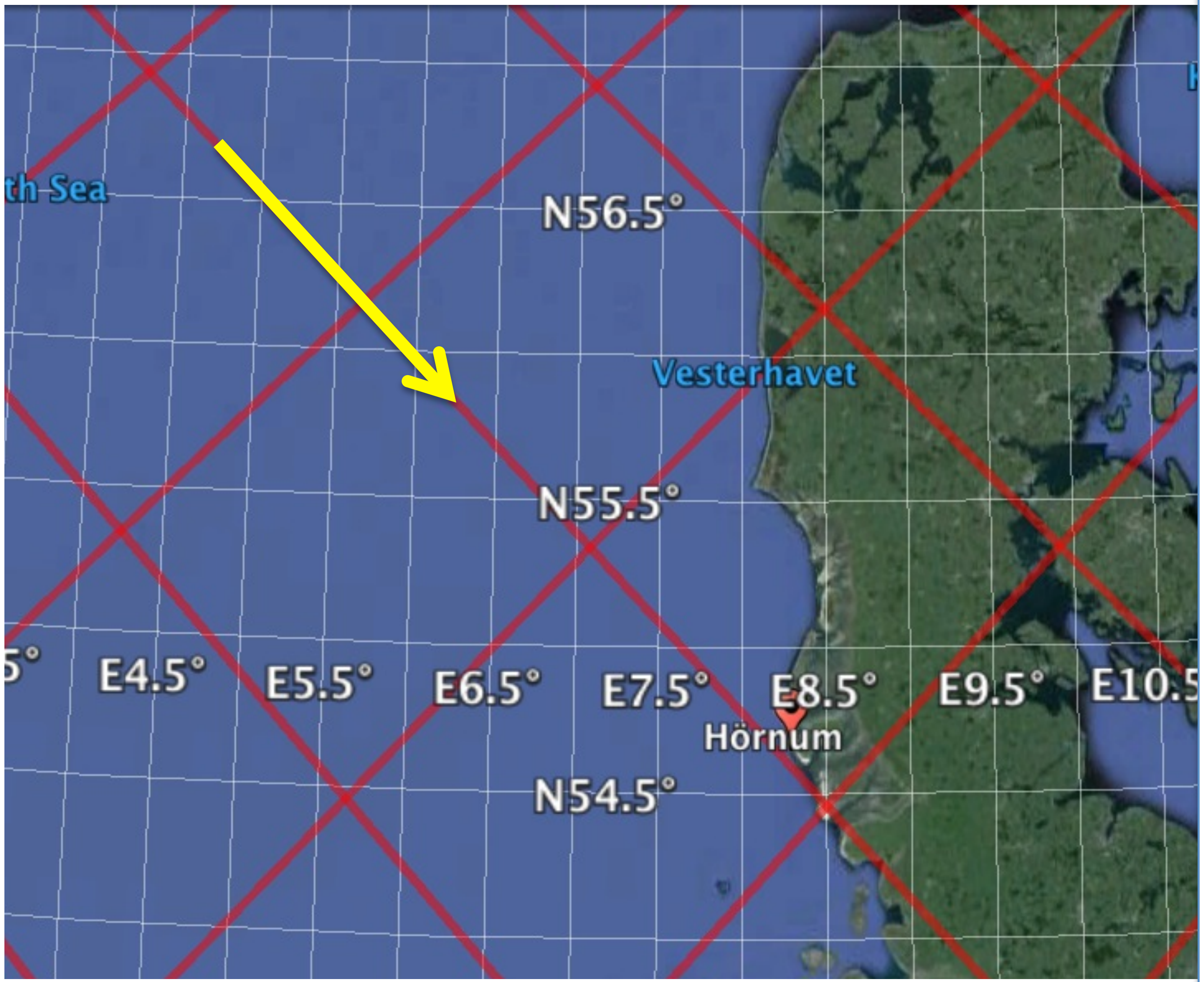
North Sea Storm, 10/11 Jan 2015

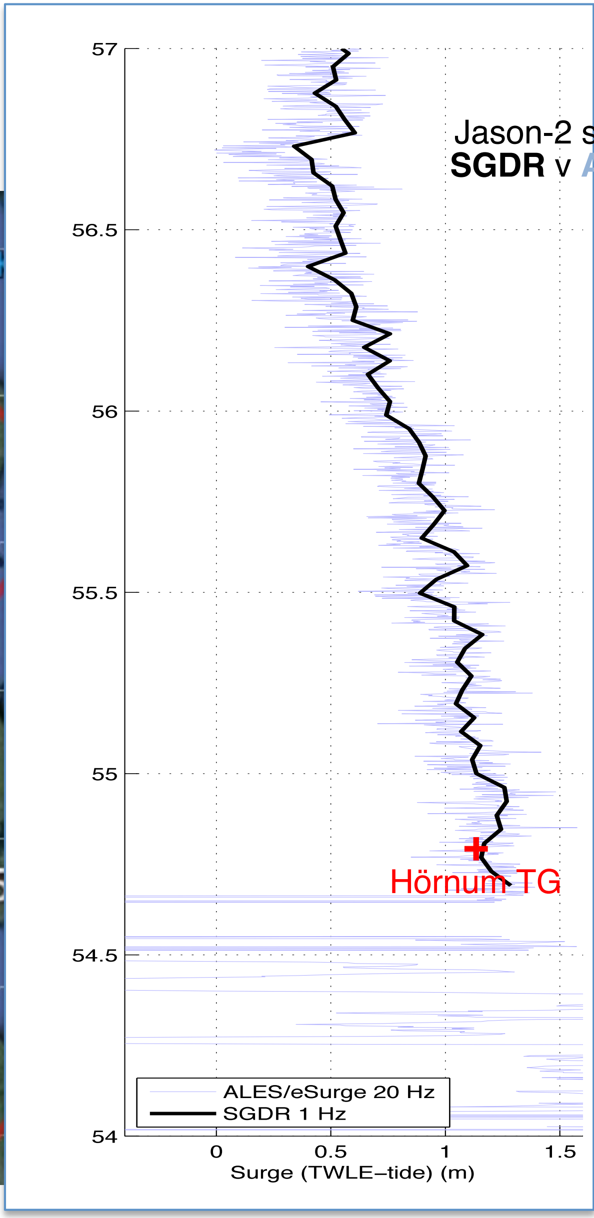



eSurge
esa
Measured and Estimated Tide Level – 1512 – Germany – Hörnum
9
8.5
8
7.5
7
6.5
6
5.5
5
4.5
4
3.5
Time:12:55:00 (11 Jan 2015)
Measured Tide Value: 6.34
Estimated Tide Value: 5.117
Difference : 1.223
12:00
00:00
10 Jan 2015
12:00
00:00
11 Jan 2015
12:00
00:00
12 Jan 2015
12:00
Date (UTC)
Measured value: Germany – Hörnum (1512)
Tide estimated value (Lon: 8.297 / Lat: 54.758)
Highcharts.com
7 Days
3 Days
Select Date
Estract ASCII data
European Commission
©Developed by JRC - Institute for the Protection and Security of the Citizen (IPSC)

eSurge ALES J2 altimeter profile

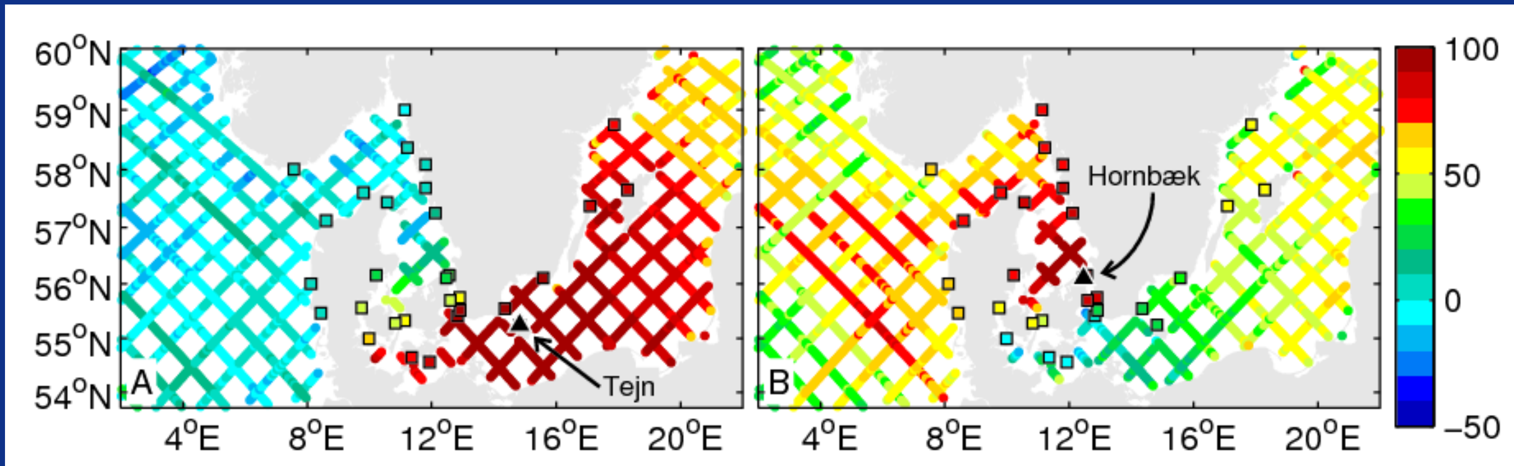
(P. Cipollini)

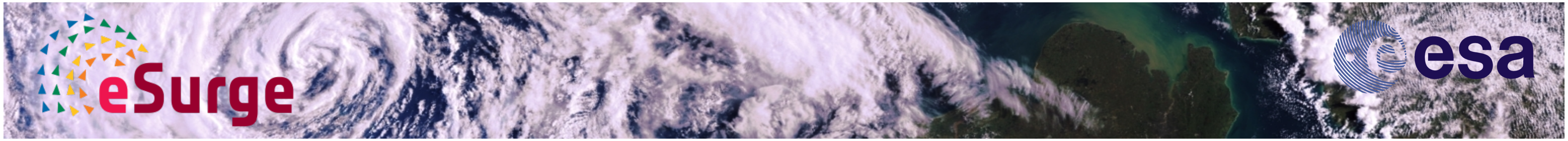




Statistical blending Method

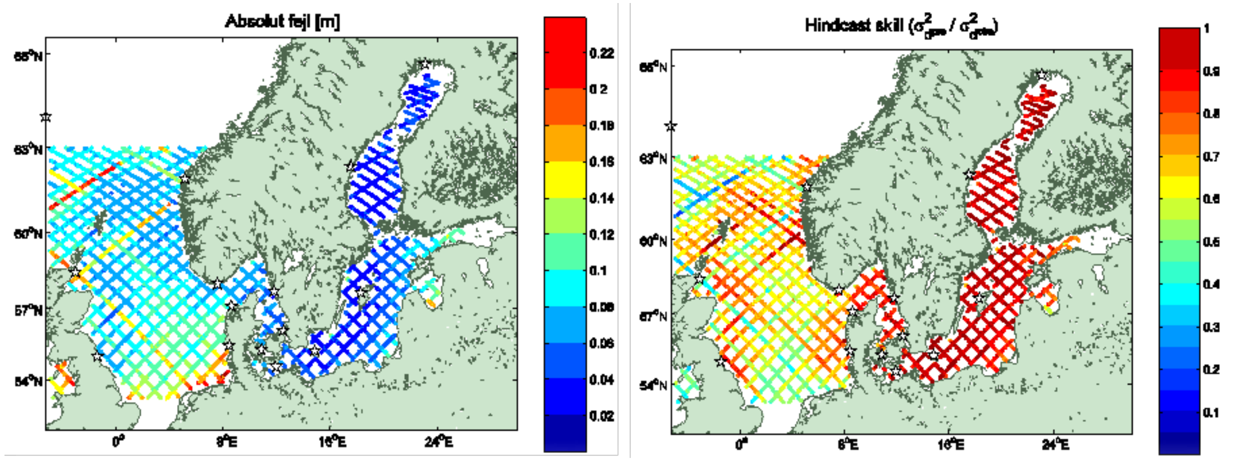
- Multivariate regression where data from 17 tide gauge stations are regressed onto the satellite altimetry observations (Høyer et al., 2002, Madsen & Høyer, 2007)
- Tide gauges selected based on the correlation with satellite observations
- Allows real-time sea level estimation in points where satellite data are available
- Sea level estimate independent upon ocean and atm. Model performance
- Assumes stationarity
- New version for eSurge uses coastal altimetry observations

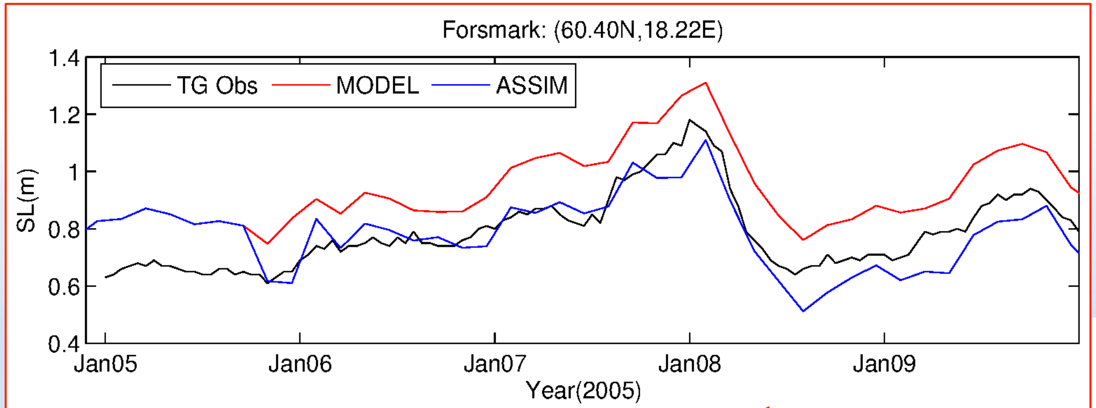


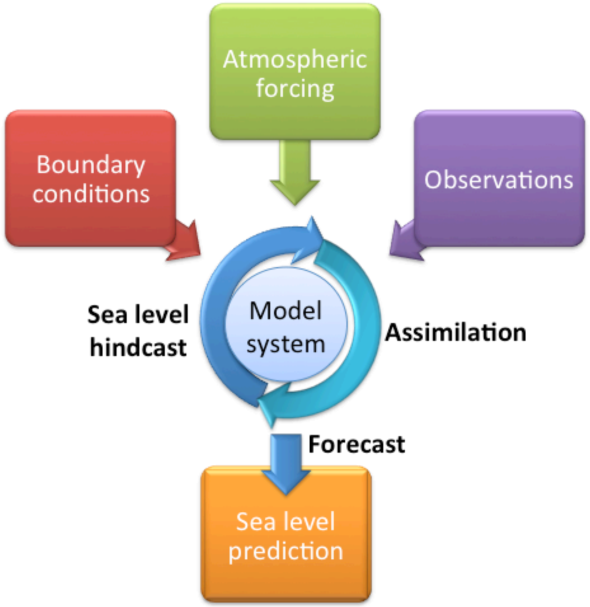


DMI

DMI's modelling team are collaborating with their forecasters to see how best the results of their experimental blending approach can be used.

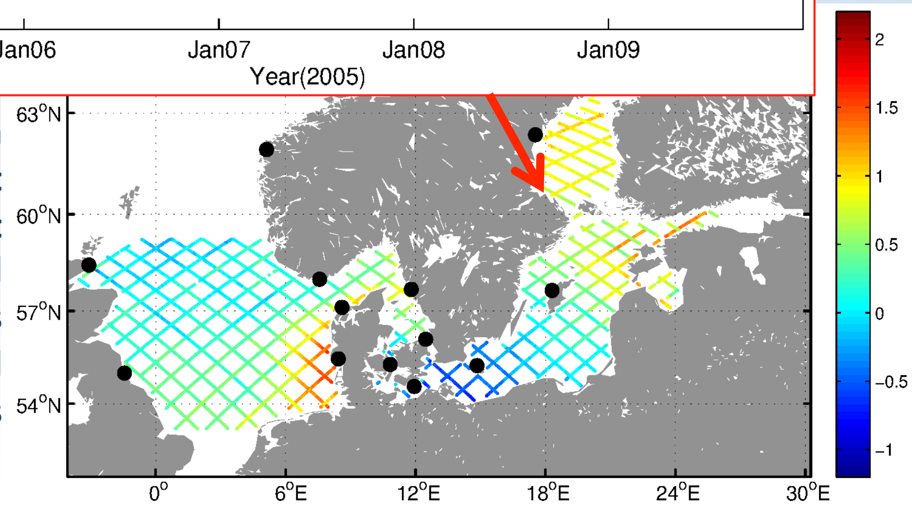




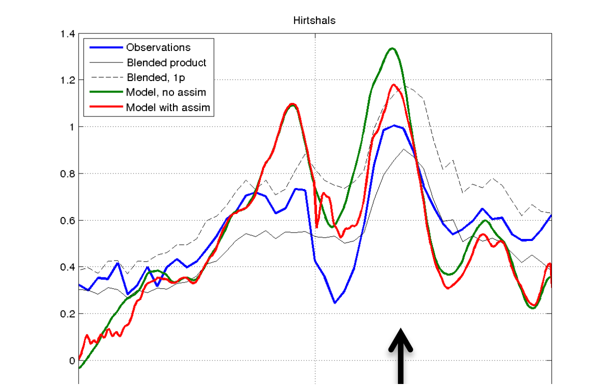


Validation against independent sea level observations show model improvements

Danmarks Meteorologiske Institut
Danish Meteorological Institute

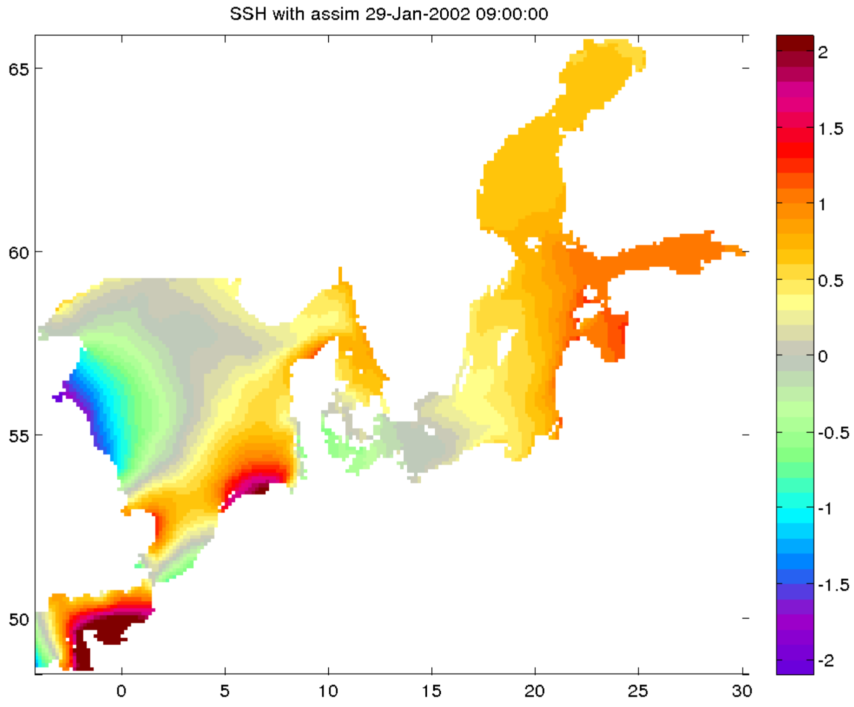


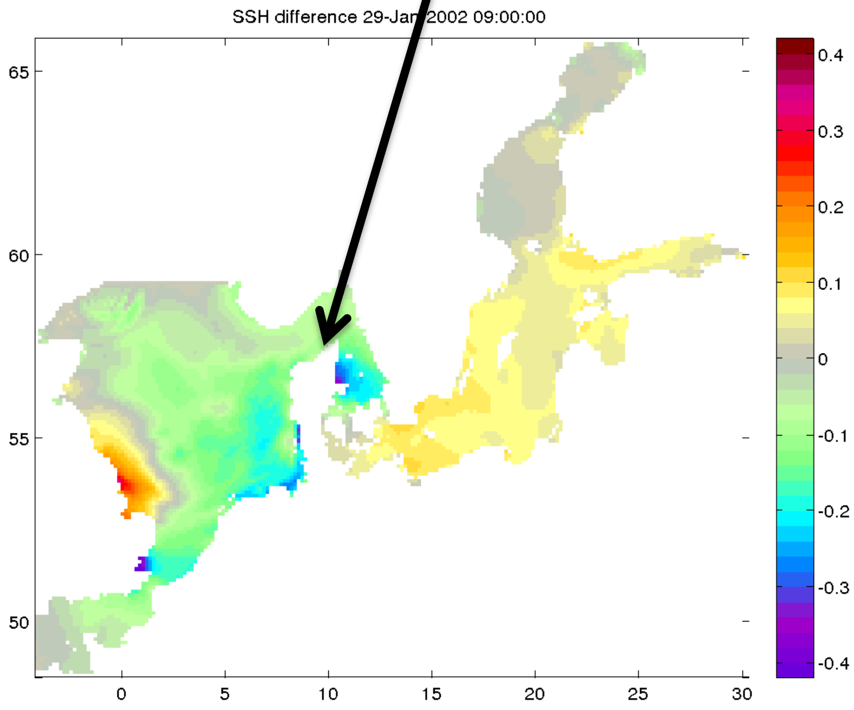
Assimilation experiment – storm surge case example



29-01 2002 09:00

Peak bias reduction 15 cm

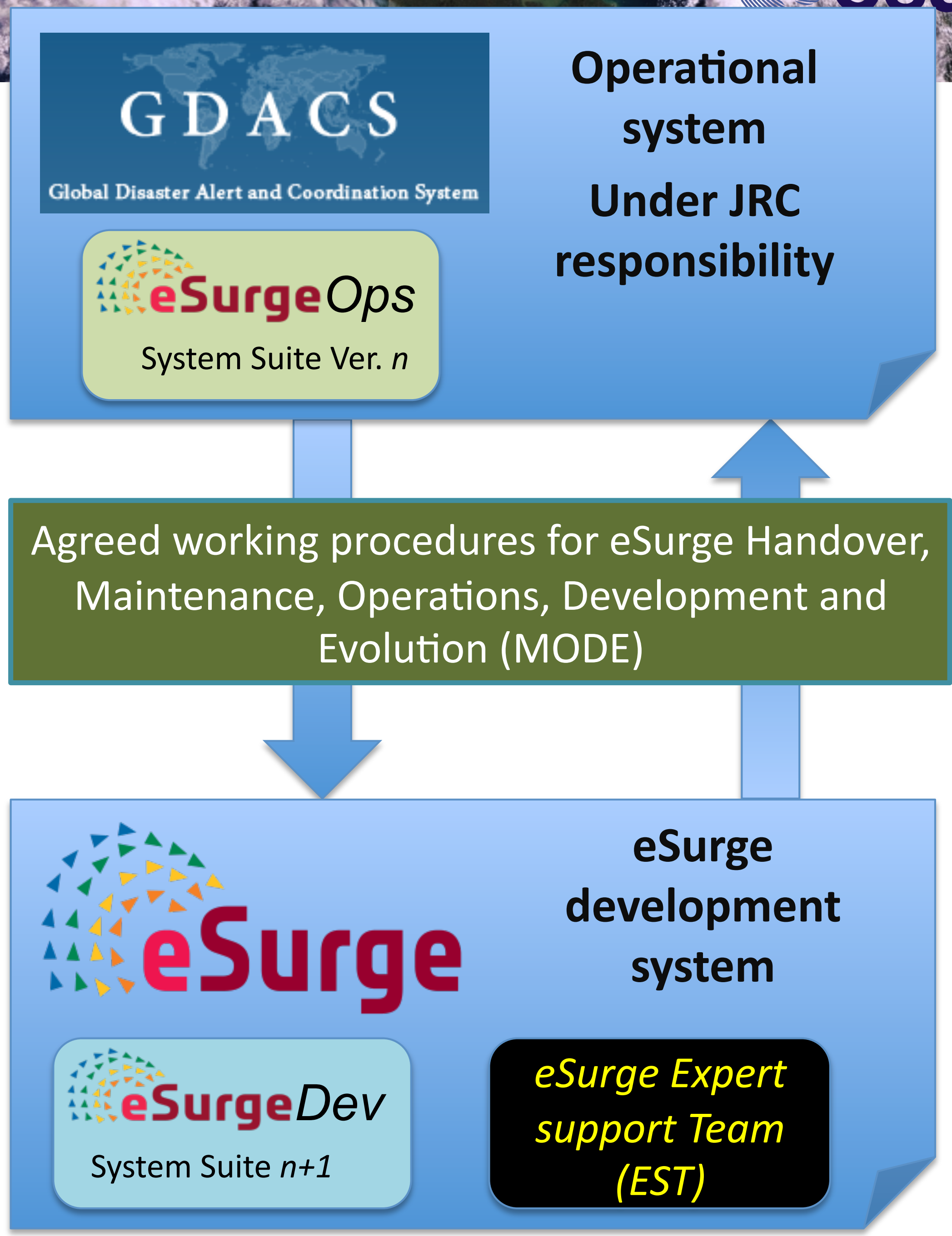




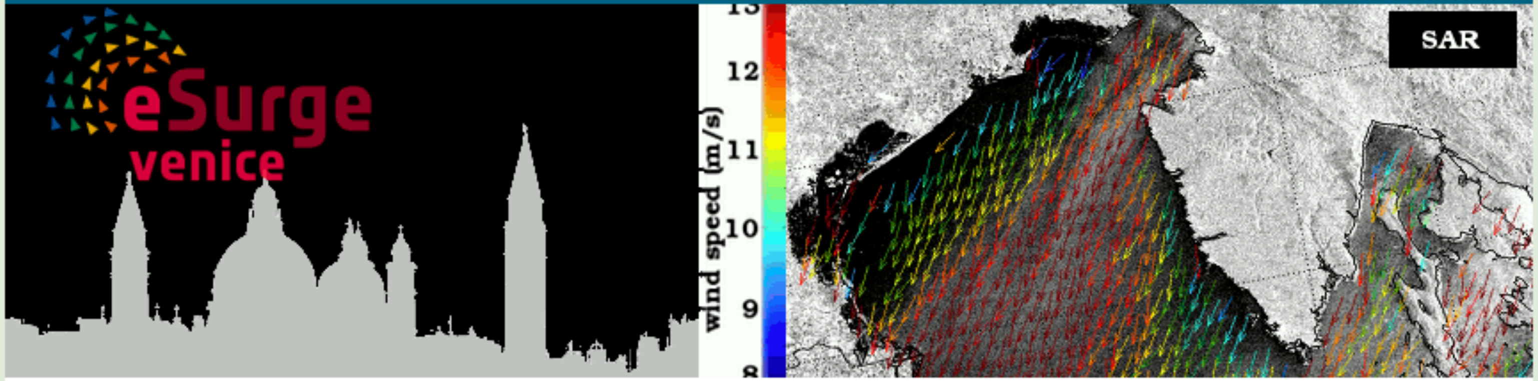
eSurgeOps: Operational eSurge (Version n)
Parallel suite (ver. n+1) is developed by eSurge to support operations.

MODE Management: Relationship, cost and job management between GDACS (customer) and eSurge (provider)

eSurgeDev: Parallel suite (Version n+1) for scientific development and maintenance. Activities requested by GDACS via OMDE and implemented via eSurge Expert Support Team (EST)

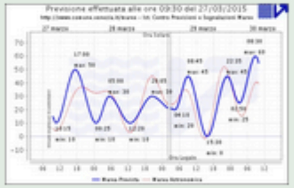


Home | Storm Surge | Selected Events | About Us | Documentation | Contact Us



Sea Level Forecast

Normal tide -50 ÷ +79



About eSurge-Venice

eSurge-Venice is funded by the European Space Agency . The consortium participating to the project is composed by three Institutes belonging to the National Research Council of Italy, the **Istituto di Scienze dell'Atmosfera e del Clima** (ISAC), the **Istituto di Scienze Marine** (ISMAR) and the **Istituto di Biofisica** (IBF), and by the **Istituzione Centro Previsioni e Segnalazioni Maree** (ICPSM) of the Venice Municipality.

esa

Home

The eSurge-Venice Project

eSurge-Venice (ESA Storm Surge for Venice) is a project funded by the European Space Agency, part of its Data User Element (DUE) programme. It aims to increase the usage of Earth Observation (EO) satellite data, from both ESA and other spacecraft, within the storm surge community. It runs in tight connection with the ESA DUE Storm Surge project eSurge, which is developing an open-access database (SEARS: Surge Event Analysis and Repository Service) to give users easy access to EO and other data relevant for studying storm surges. SEARS includes the data selected by the eSurge-Venice project.

Basically, the eSurge-Venice project is:

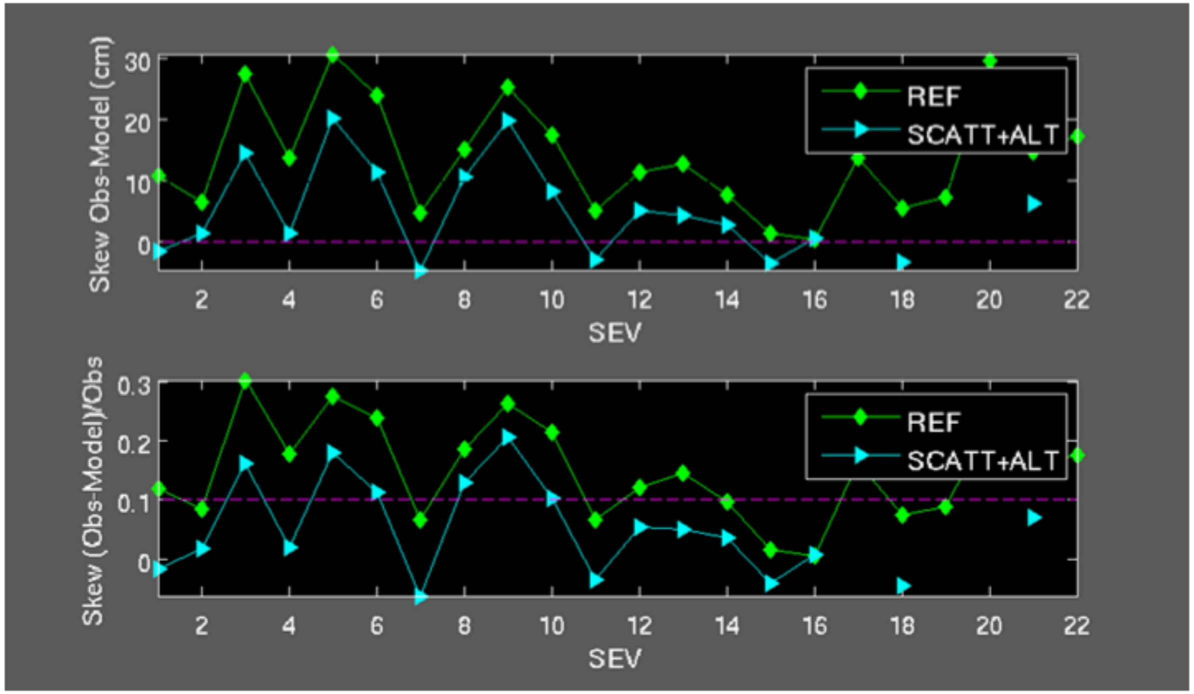
- Selecting a number of Storm Surge Events occurred in the Venice lagoon in the period 1999-present day
- Providing the available satellite EO data related to the Storm Surge Events, mainly satellite winds and altimeter data, as well as all the available in-situ data and model forecasts
- Providing a demonstration NRT service (*eSurge-Venice live*) of EO data products and services in support of operational and experimental forecasting and warning services
- Running a number of re-analysis cases, both for historical and contemporary storm surge events, to demonstrate the usefulness of EO data

Running a number of re-analysis cases, both for historical and contemporary SEVs, to demonstrate the usefulness of EO data within the Venetian storm surge community

Assimilating altimeter TWLE* and using the modified ECMWF winds

Figure reports the skew surge obtained using the original ECMWF forecast data as forcing (REF) and the SCATT forcing plus the assimilation of TWLE* altimeter data (SCATT+TWLE*). Even if the main improvements are brought by the SCATT, there is a further decrease of the errors resulting by the combination of the two methods. This is because the wind mitigation and the TWLE* assimilation reduce the errors ascribed to different sources, i.e. ***the wind forcing and the initial status of the sea level***. The RMS error decreases from 16.3 cm to 9.0 cm.

TWLE* = TWLE-astronomical tide



Training Event: Cork 2014

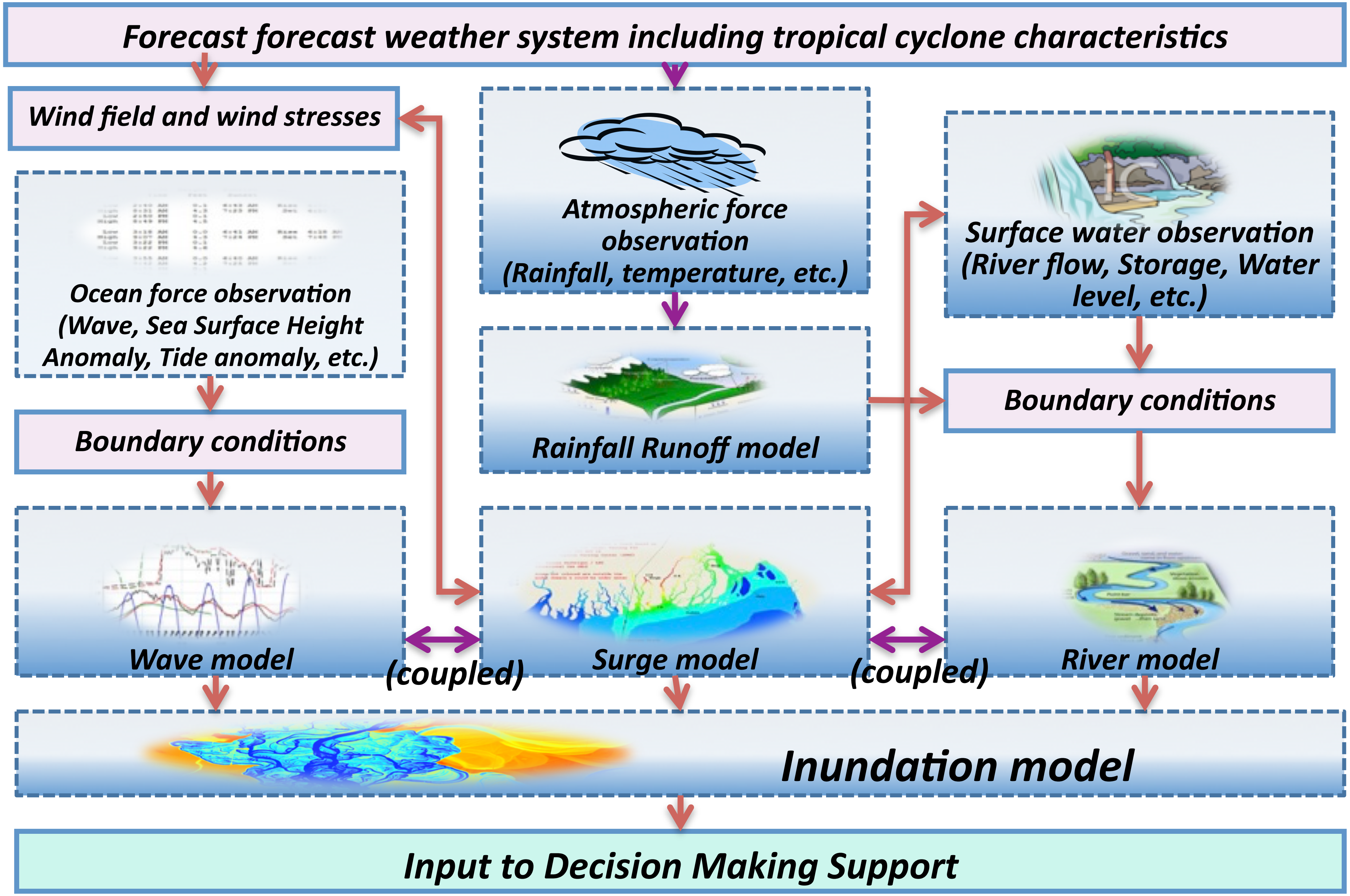
- High interest in using satellite data more, either to augment existing data or for new ways of working.
- At moment direct interest is in winds data.
- Significant interest in using altimetry operationally, and especially the Virtual tide gauges concept.
- Need for more discussion and networking between different skill groups, working towards collaborative solutions.
- Courses such as these are fundamental to developing a new storm surge EO community.

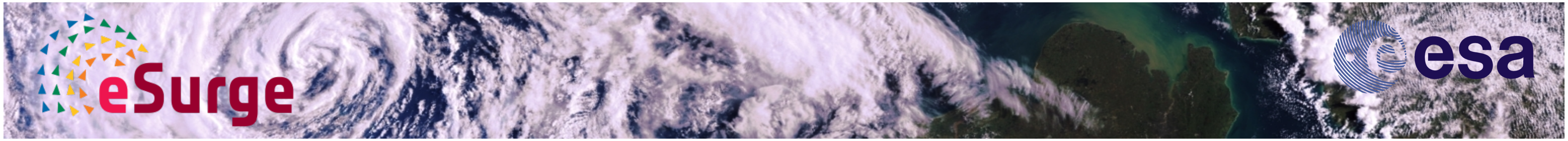
Key conclusion: course was too short!

Key successes

- Building storm surge network (SSN), developing a scientific community **where there was none before**, and meeting pent-up demand from many users.
- Developing, implementing and operating a powerful and flexible system (SEARS) and web front end to allow users to visualise and access data for Storm Surge applications.
- Developing a new **altimetry processor, ALES, tuned to the Storm Surge application** and improving previous altimetry processors providing seamless operation in open ocean and coastal zones.
- Demonstrating and promoting **how** altimetry can be used operationally for Storm surge prediction and thus **paving the way for application of Sentinel 3 SRAL data**.
- Providing **the first EO storm surge training material on the web**, as well as the first such course that we are aware of.
- **Extending user base** for high-resolution wind data and altimetry data.

eSurge esa


Forecast forecast weather system including tropical cyclone characteristics
Wind field and wind stresses
Atmospheric force observation (Rainfall, temperature, etc.)
Surface water observation (River flow, Storage, Water level, etc.)
Ocean force observation (Wave, Sea Surface Height Anomaly, Tide anomaly, etc.)
Rainfall Runoff model
Boundary conditions
Boundary conditions
Wave model
(coupled)
Surge model
(coupled)
River model
Inundation model
Input to Decision Making Support



“eSurge represents the "coming of age" for coastal altimetry and satellite data in support of storm surge forecasting. Its value is underlined by the fact the the JCOMM Expert Team on Waves and Coastal Hazards (ETWCH) has adopted the eSurge project under its intersessional workplan ….

“eSurge also acted to galvanise the international storm surge community, as can be seen from the enthusiastic uptake of the training workshops. It is my intention that the international storm surge community should unite with the wave modelling community through the biennial Wave Forecasting and Hindcasting Workshops. Storm surges should become a permanent element of this meeting and within the programme there is a clear need for a satellite observation component.

“As Chair of the ETWCH I will ensure that this unification takes place and that the value of satellite observations are recognised”

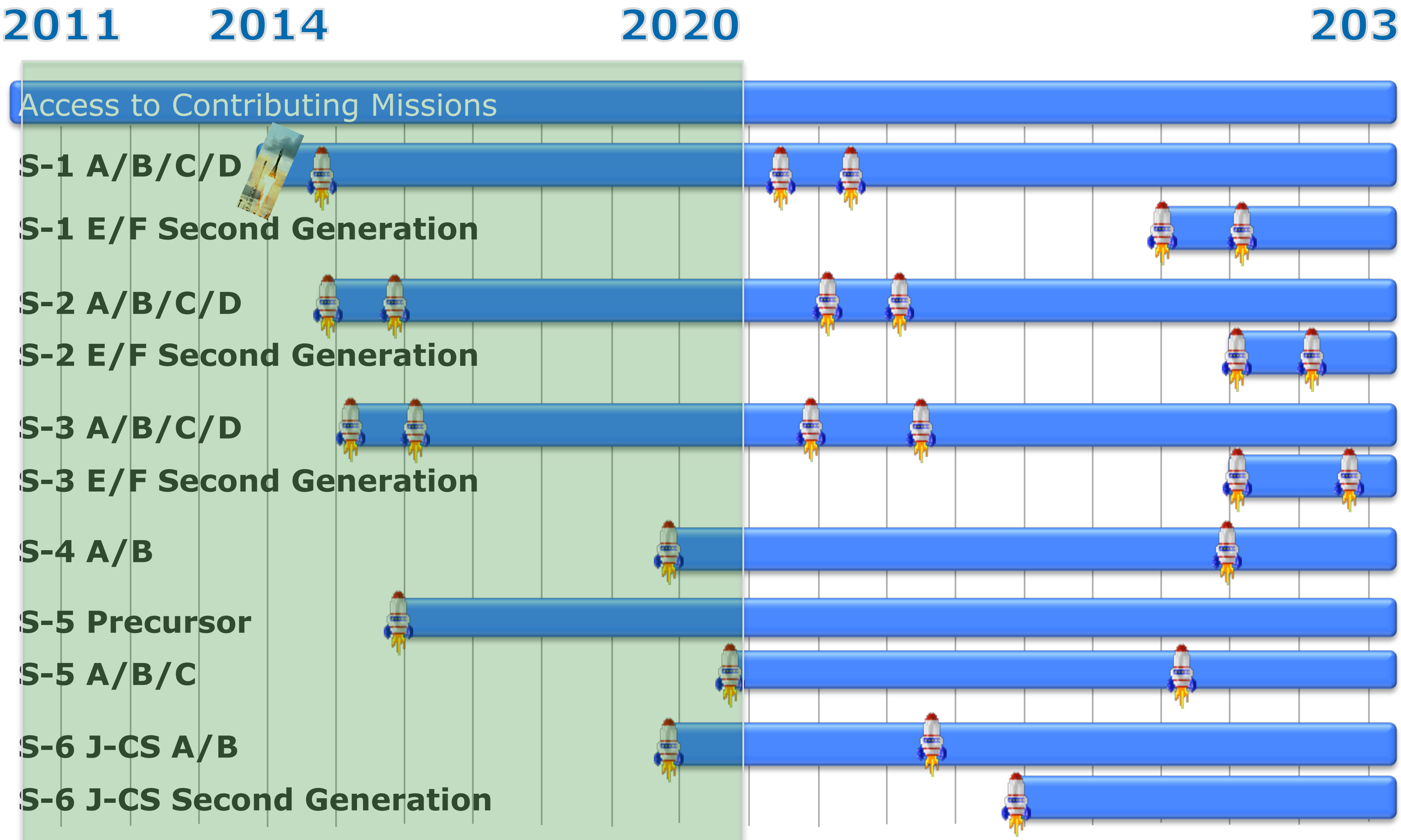
Kevin Horsburgh, NOC, ETWCH and JCOMM Chairman

copernicus
observing the earth

esa

A long-term operational perspective…

esa



Copernicus European Space Agency

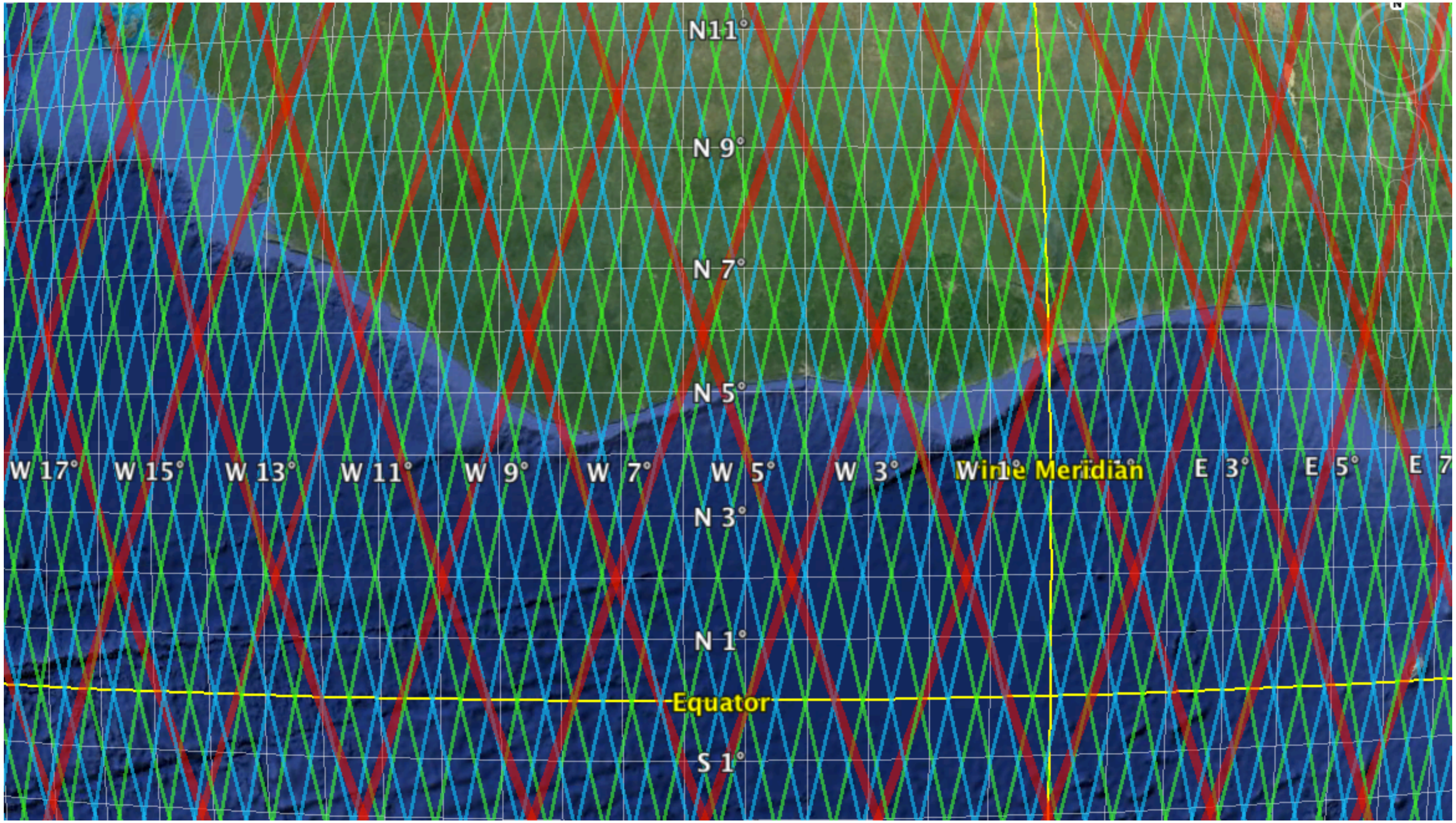
The Copernicus Altimetry Constellation

Fig. 1: Jason-CS in flight configuration (credits: Astrium)

Sentinel-6 / JASON-CS: Reference Orbit

Sentinel-3: Polar Orbit

S6 reference orbit and S3 sun synchronous polar orbit of the Copernicus altimetry constellation

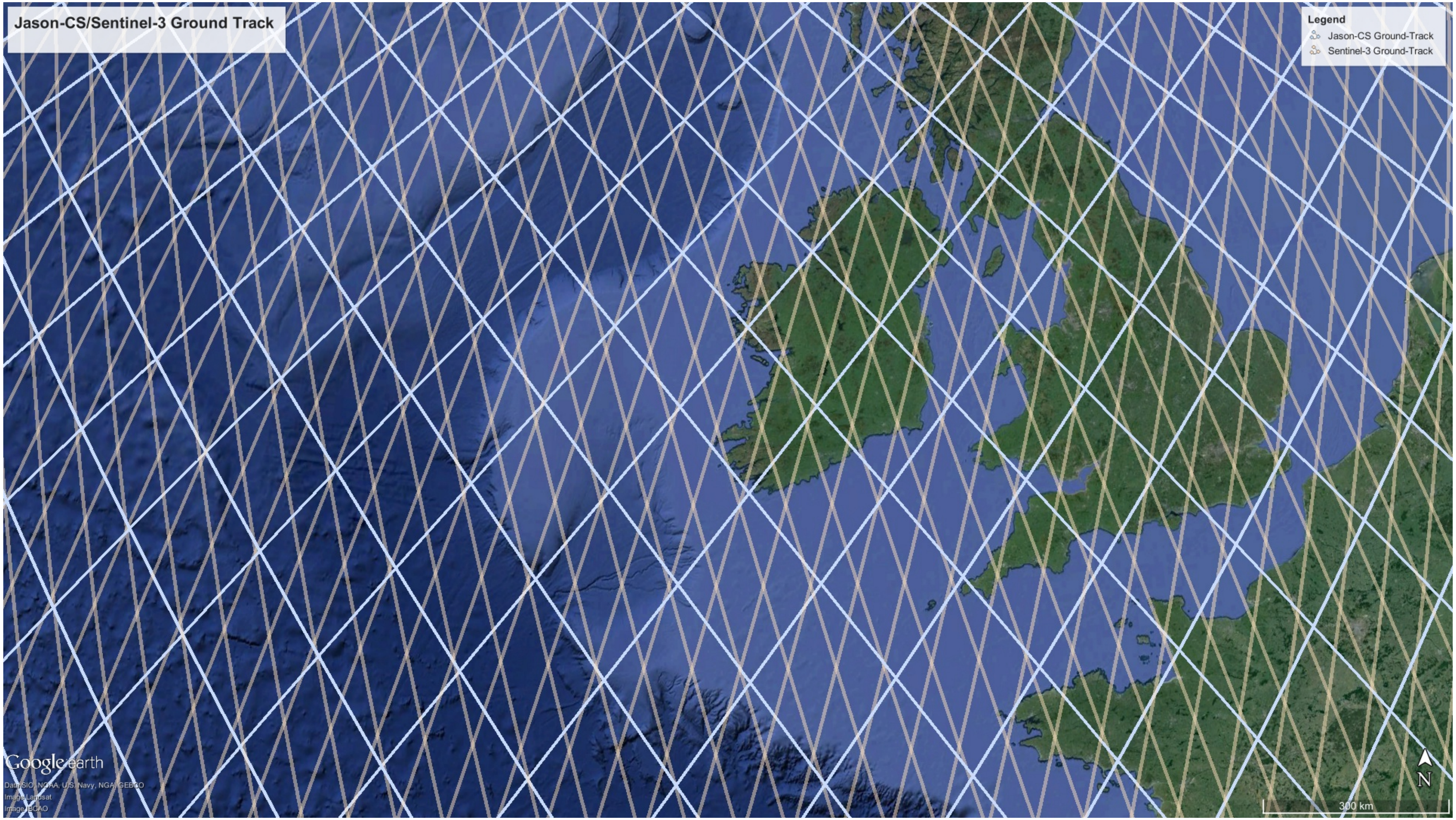


Sentinel-3A
Sentinel-3B
Sentinel-6/JASON-CS

European Space Agency

Orbit complementarity

- The Sentinel-6 orbit is complementary to Sentinel-3

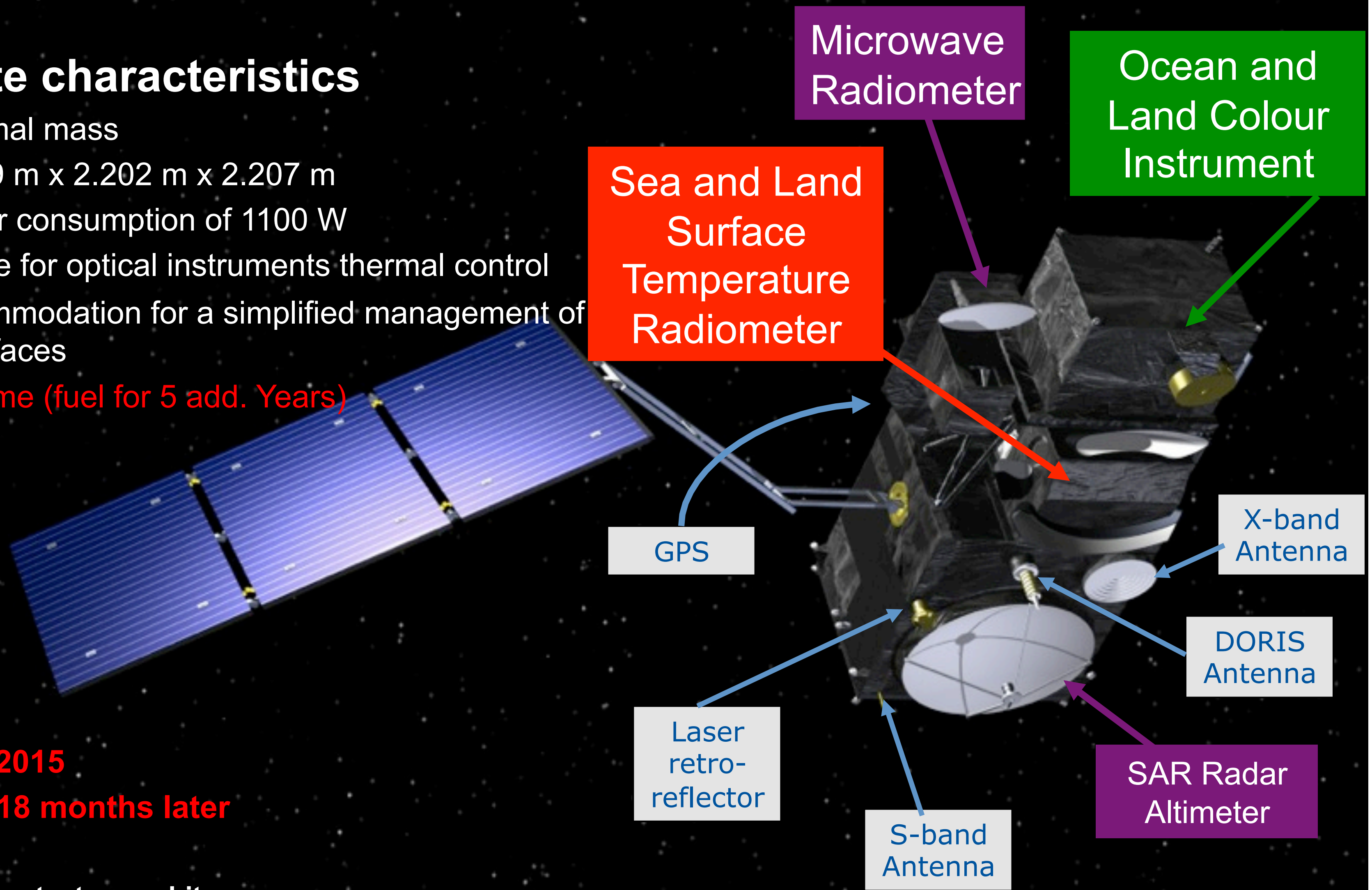


Sentinel-3: The Copernicus Medium Resolution Ocean and Land Mission

esa

Main satellite characteristics

- 1250 kg maximal mass
- Volume in 3.89 m x 2.202 m x 2.207 m
- Average power consumption of 1100 W
- Large cold face for optical instruments thermal control
- Modular accommodation for a simplified management of industrial interfaces
- 7.5 years lifetime (fuel for 5 add. Years)



- **Launch S3A 2015**
- **Launch S3B 18 months later**

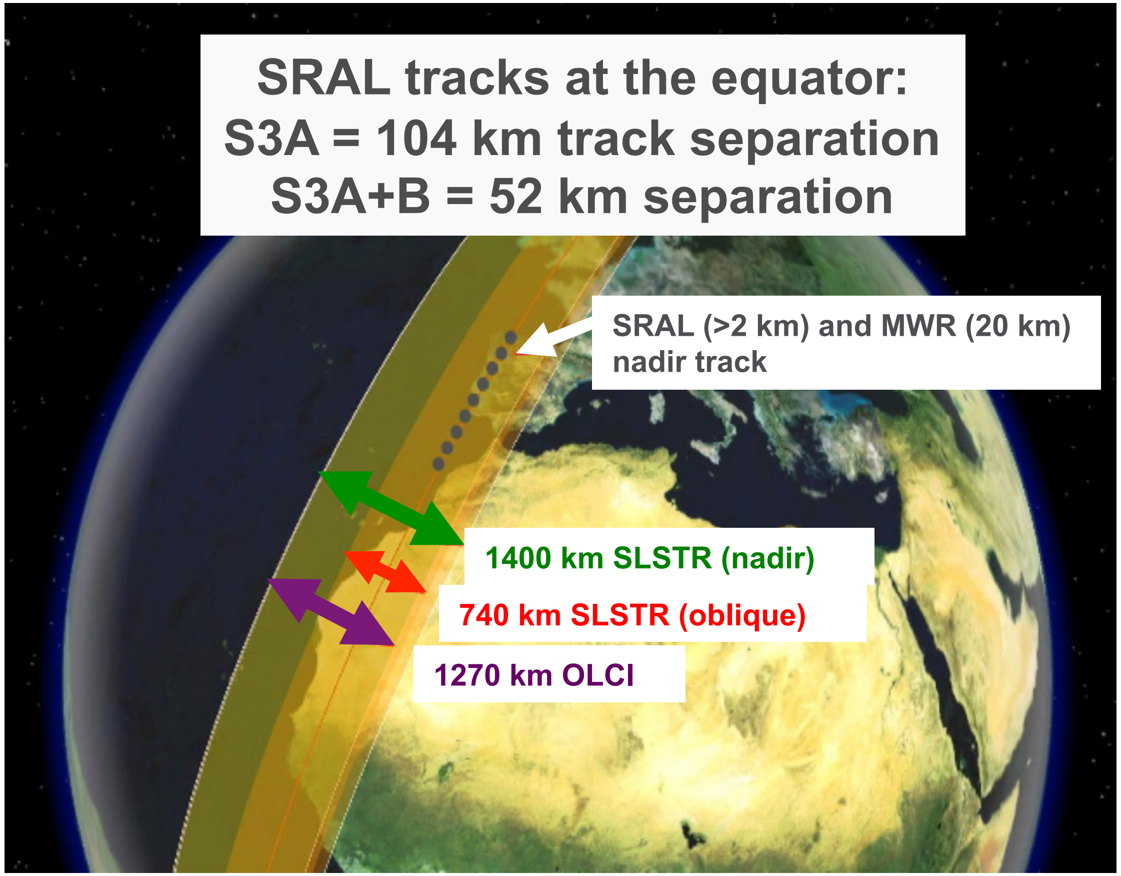
Observation:

- **1 ground contact per orbit**
- **3h delivery timeliness (from satellite sensing)**

Sentinel-3: Satellite Orbit details

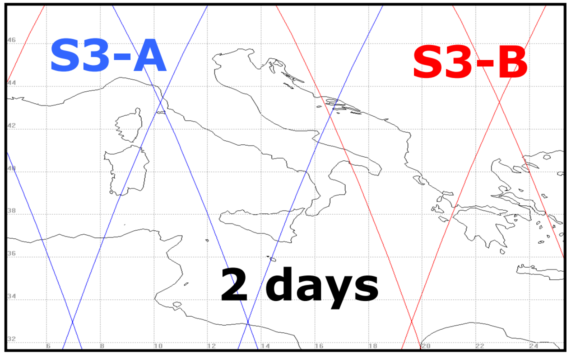
esa

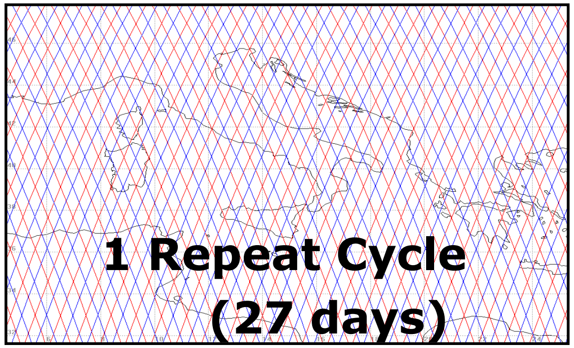
Instrument Swath Patterns



Orbit type	Repeating frozen SSO
Repeat cycle	27 days (14 + 7/27 orbits/day)
LTDN	10:00
Average altitude	815 km
Inclination	98.65 deg

Ground Track Patterns





SRAL orbit drivers:

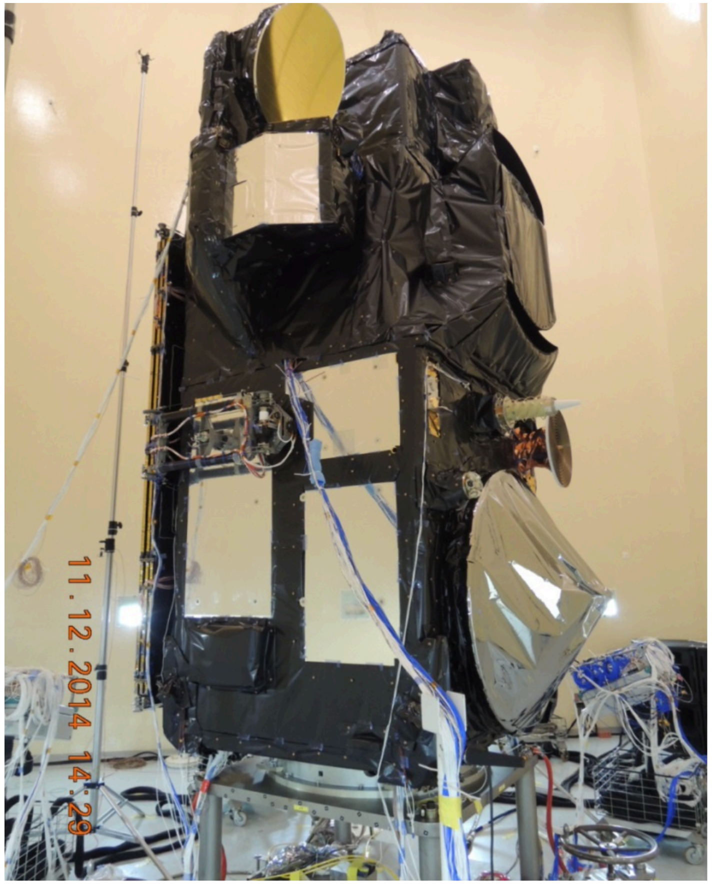
- Ground track repeatability,
- Dense spatial sampling

Orbit control requirement:

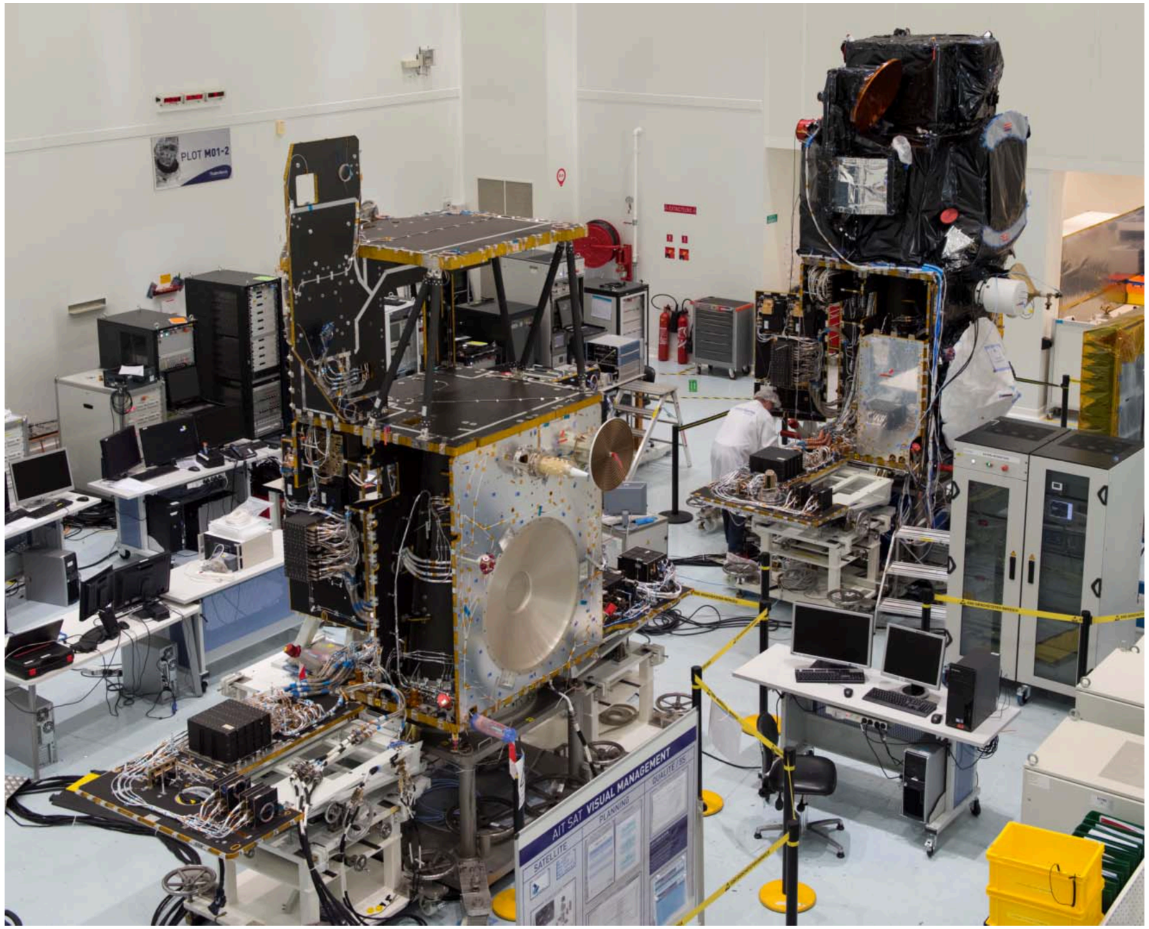
- Ground track dead-band ±1km

Copernicus European Space Agency

SRAL: Technical Status



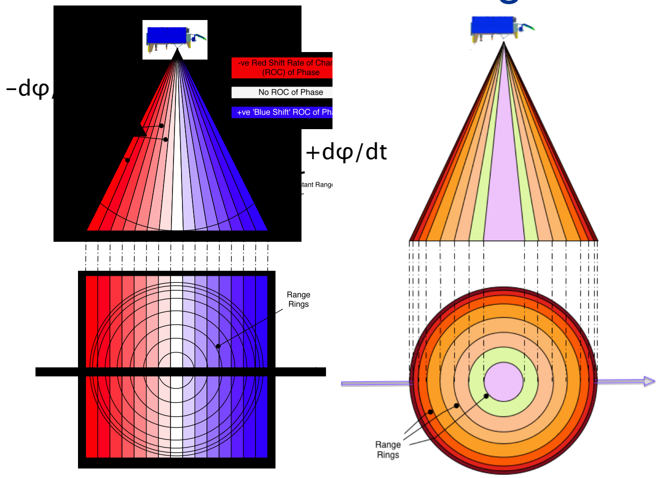
S3A Satellite on stand within the Acoustic Chamber at Thales Alenia Space in Cannes (Courtesy of TAS-F)

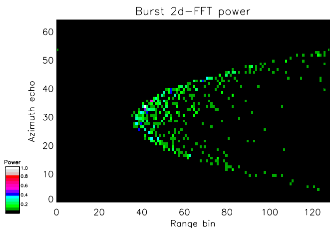


S3B (left) and S3A (Right) Satellites close to each other within the Clean Room at Thales Alenia Space in Cannes few days ago

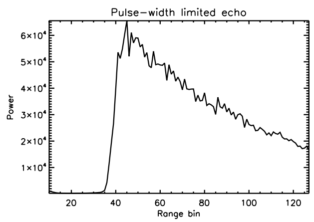
Data Processing

Level 1A provides complex echoes at the instrument timing: Allowing azimuth and Brown echo generation



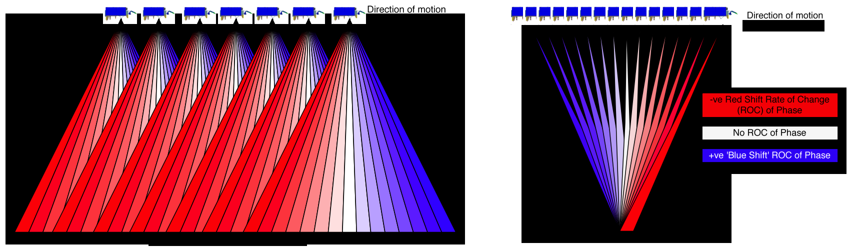


2D FFT power
processed from a burst

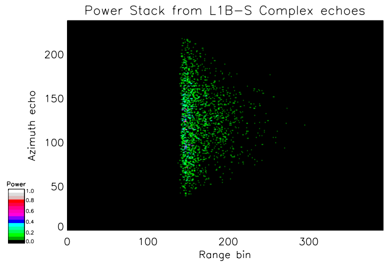


Pulse limited echo

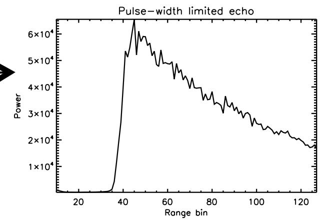
Azimuth Processing provides Complex Stack Data (L1B-S) and Multi-looked echoes (L1B)



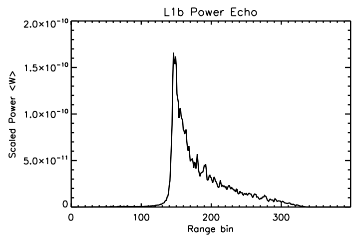
Level1B-S:
Stack Power echoes from complex stack allow surface characterisation



Level 1B:
Multi-Looked Power echoes



LR

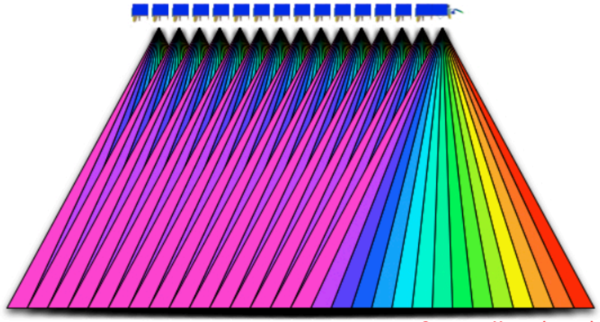


HR

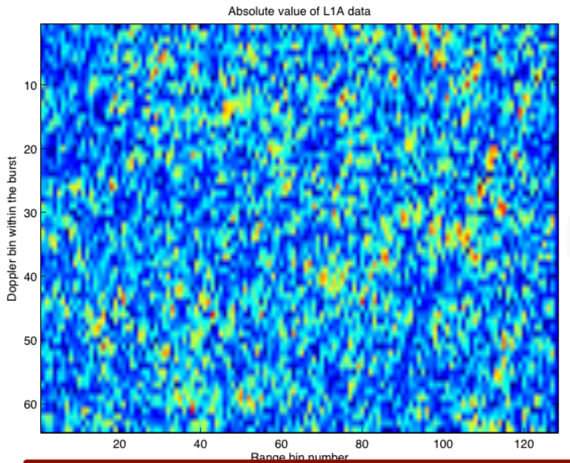
European Space Agency

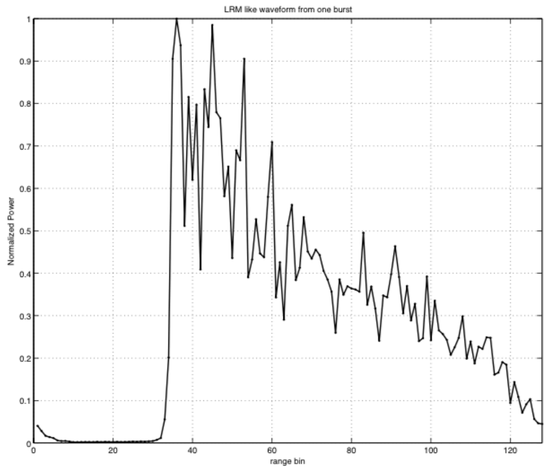
L1A ~ "Calibrate FBR"

- **Bursts (NOT STACK!!)** including geolocation information
  - Lat, lon at mid-burst
- **Complex waveforms** (scaled to reduce file size)
- **Navigation information included**
  - Referred to mid-burst
- All information to generate L1B-S and in turn L1B
- **Geophysical corrections included**
- **Contains all star trackers info, as well as identification of which is in use**
- **Data volume** → similar to L0
- **Potential uses (to be revisited with the case studies):**
  - Generation of pseudo-LRM
  - Further investigation of pulse-to-pulse correlation (revisit Walsh work)
  - Study of different beam formation methods (FFT - exact or approximate or z-transform, for example)
  - Allows for investigating new manners to process L1 dedicated to each surface under observation: Hamming, Hanning, ZP of 2, 4, etc., beam steering, etc.



Courtesy of R. Cullen (ESA)

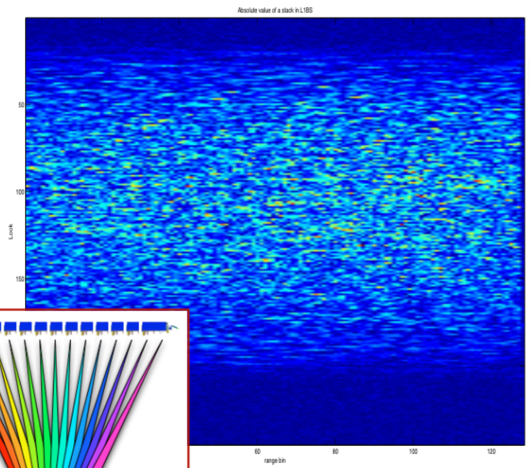




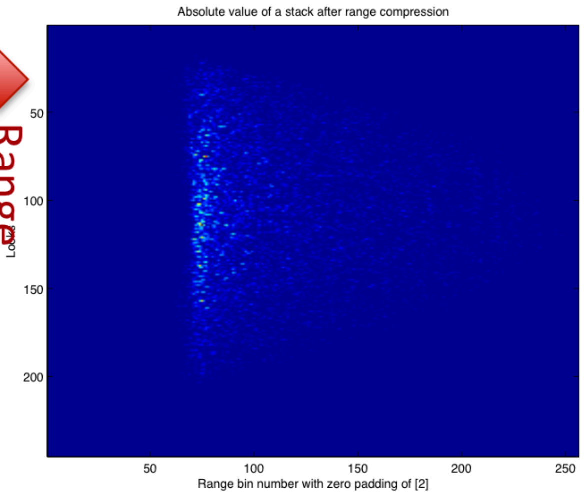
Calibrated Burst information processed @ isardSAT for the S3 MAG

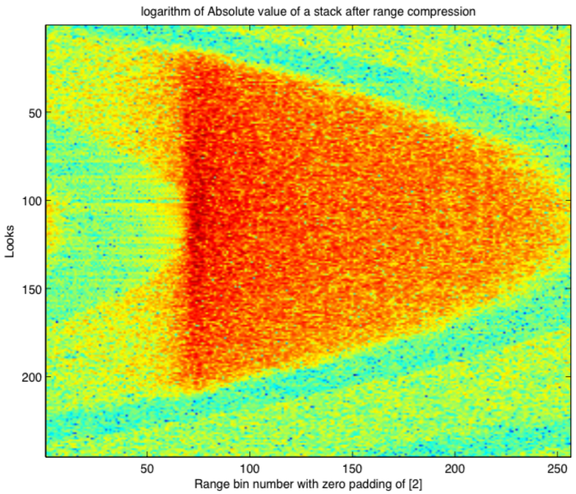
Semi- Pseudo-LRM from incoherent integrating only the burst @ the left of this slide

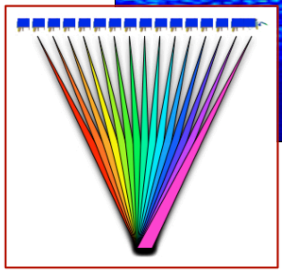
L1B-S or stack data



Range compression



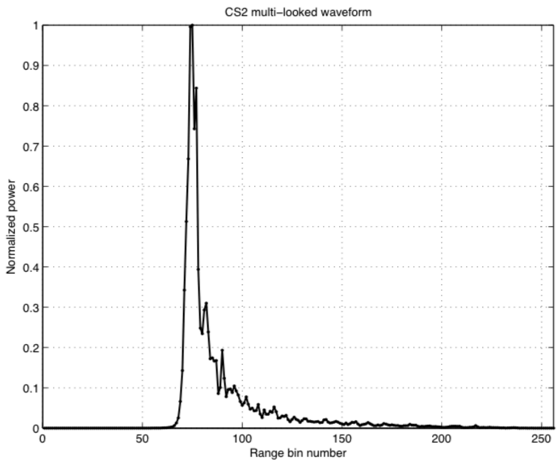




Courtesy of R. Cullen (ESA)

A ranfom stack over the Atlantic processed from CryoSat-2 with Jason-CS P4 GPP @ isardSAT

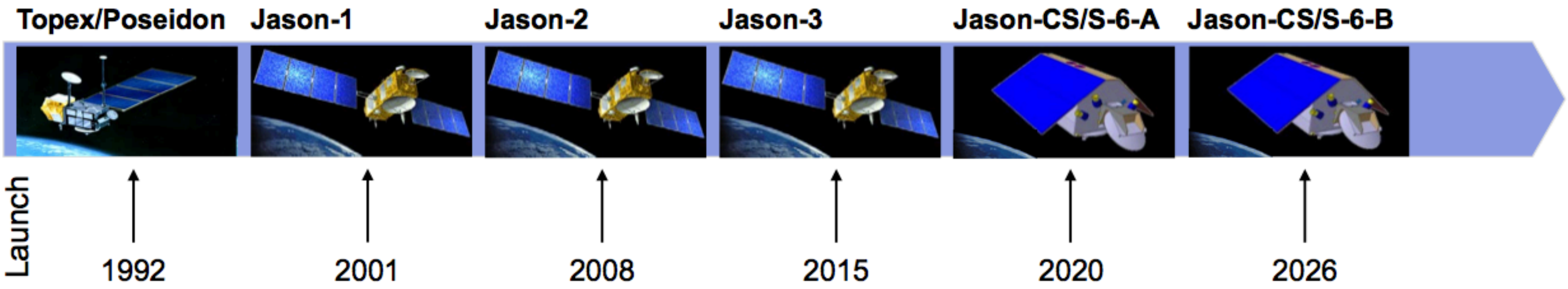
Incoherent integration



- <u>**Stack**</u> including geolocation information
  - Lat, lon of Doppler cell on the ground referred at mid-stack
- Scaled **complex waveforms** with scaling information
- **Window delay variation over stack applied** (change in on-board tracking due to orbit and surface)
- Contain all information of L1b (only range compression and multi-looking is missing)
- **Geophysical corrections included**
- **Data volume** → similar to L0
- <u>**Potential uses:**</u>
  - Allow studies on surface characterisation, detailed calibration studies (transponders, for example), beam weighting, range dilation, etc.
  - Allow for 2D retracking techniques → note SAMOSA model is a 2D model which would perfectly suit to this purpose

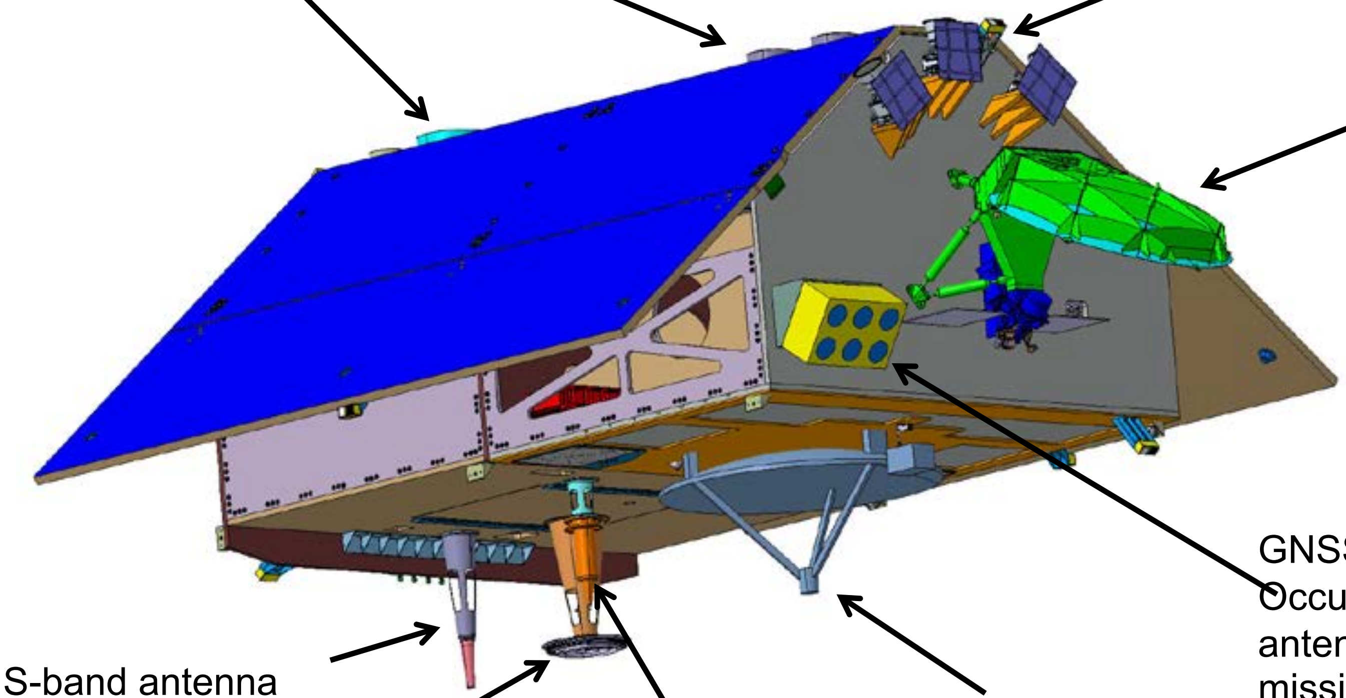
Sentinel-6/Jason-CS mission

1. The Sentinel-6/Jason-CS mission continues the long and successful ocean topography missions which started 1992 with the French/US cooperation on Topex-Poseidon and which are continued until today with the Jason missions. Jason-2 is operational since 2008 and Jason-3 is planned to be launched 2015.
2. S6/JCS-A is expected to launch in ~2020 and S6/JCS-B in ~2026



The Platform and Payload

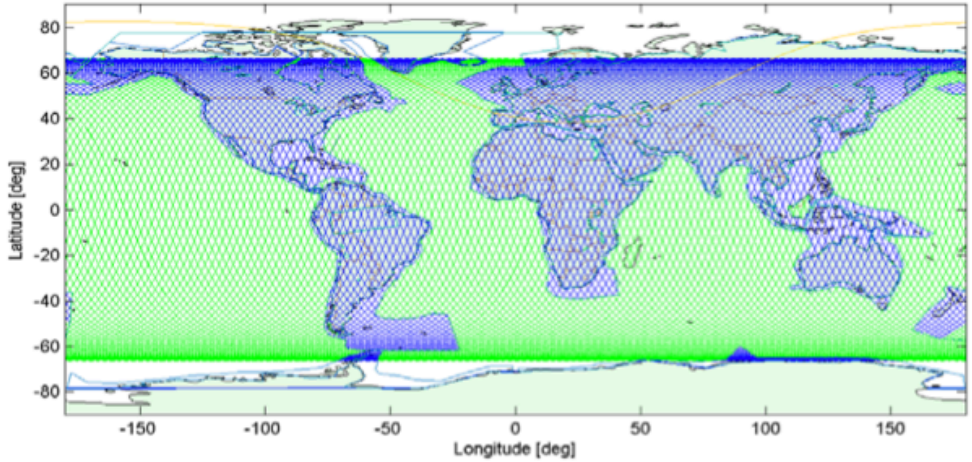
- The Platform Structure end Phase B2



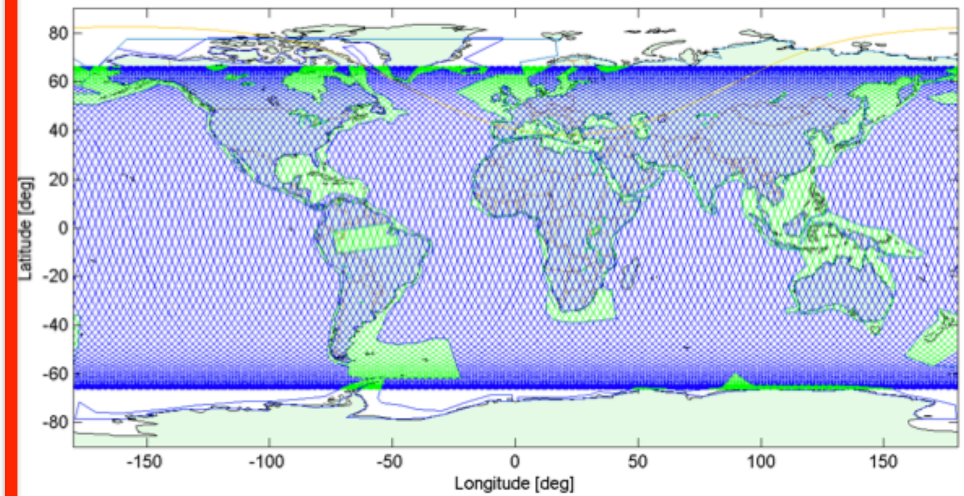
S6/JCS Mode mask analysis

Mode Mask Analysis

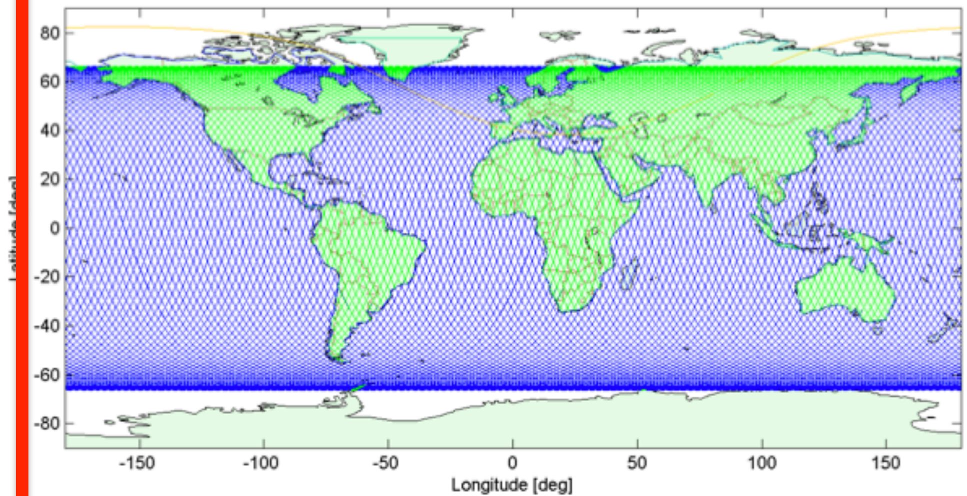
- 10 day simulations
- Determine when Jason-CS is over land, ocean and coastal regions
- Part of orbit over each region (average):
  - 58 % over oceans
  - 15 % over coastal regions
  - 27 % over land



Ground track over oceans in green



Ground track over coastal regions in green



Ground track over land in green

Low Level Requirements (Low Resolution)

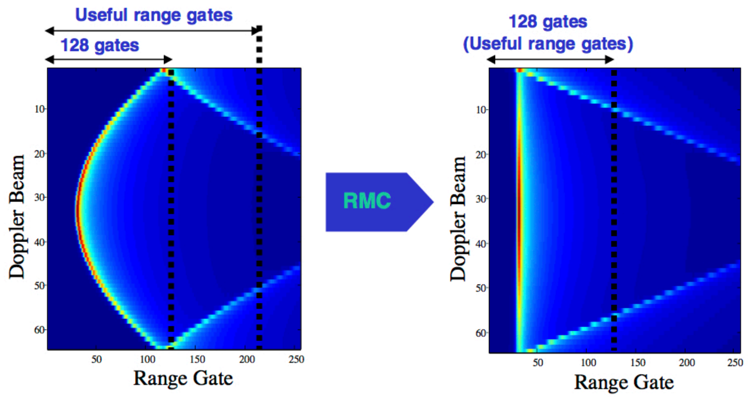
	Jason-3 (cm)	Jason-CS (cm)
Instrument range noise (MLE-3)	1.7	1.5 (1.25)
Ionosphere	0.5	0.5
Sea State Bias	2	2
Dry Troposphere	0.7	0.7
Wet troposphere	1.2	1
Altimeter Range RSS	**3**	**2.83 (2.7)**

- Blue= requirement : Red=theoretical
- Based on Non-Time Critical Product
- Jason-CS adopts the goals for Jason-3 as requirement

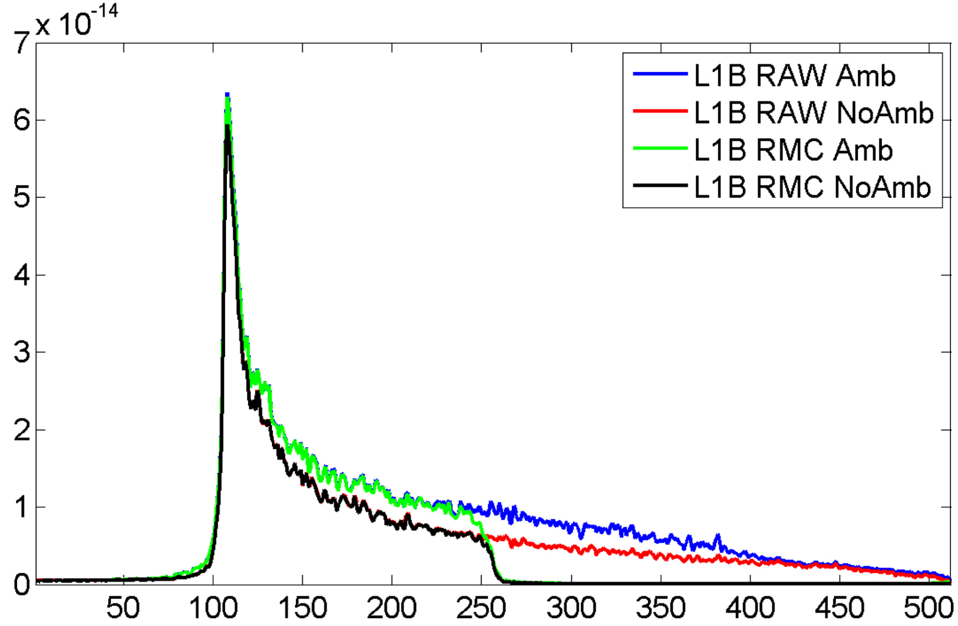
Impacts on Processing Algorithm

There are a number of side-effects

- Low PRF -> Ambiguity that needs handling
- Volume reduction via RMC (echo cut off)



Courtesy, Thales-Alenia Space

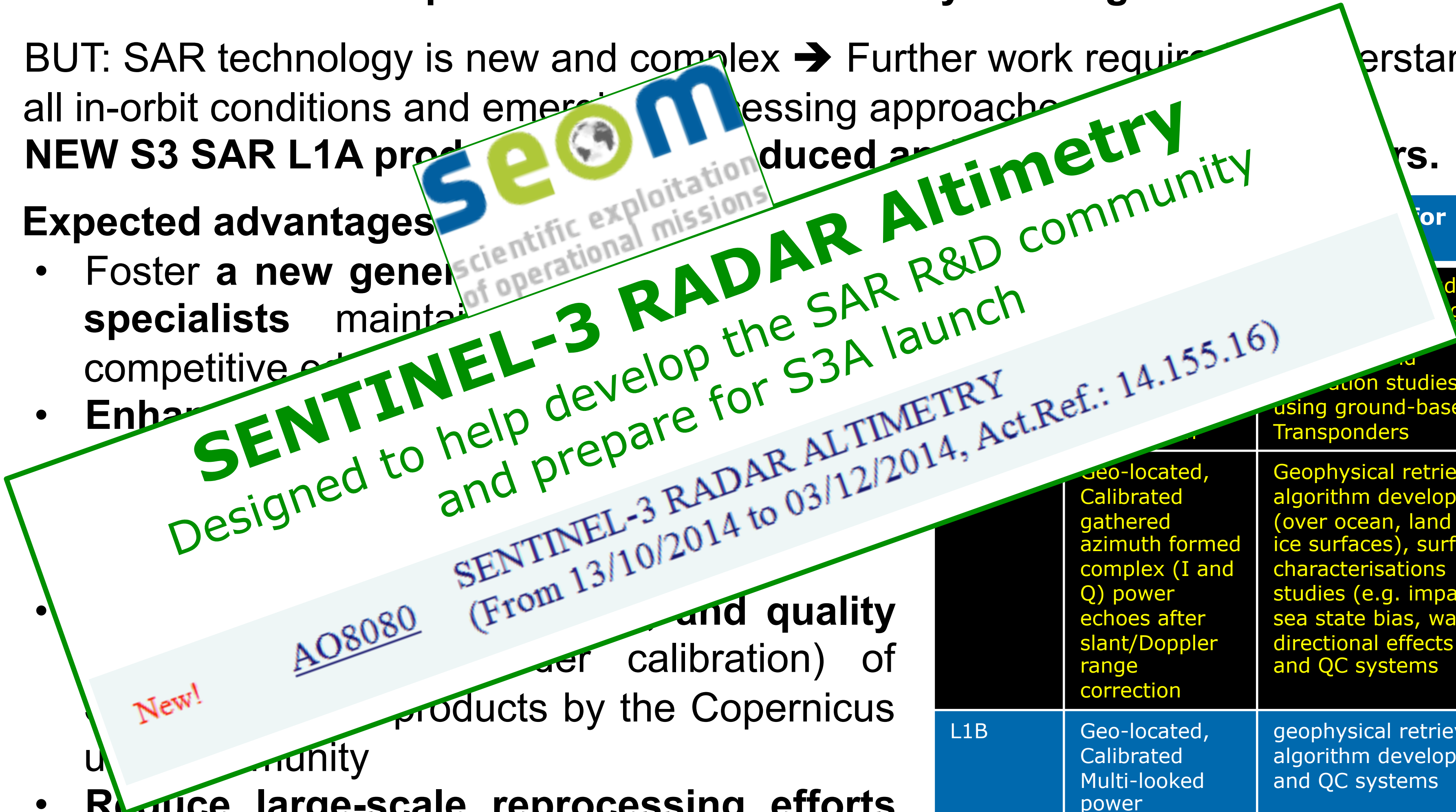


Courtesy, isardSAT

SRAL: Changed observation scenario to 100% SAR

S-3A: First mission to provide 100% SAR altimetry coverage

- BUT: SAR technology is new and complex ➔ Further work requir… erstand all in-orbit conditions and emer… essing approache…
- **NEW S3 SAR L1A pro… duced a… rs.**
- **Expected advantages**
  - Foster **a new gene… specialists** mainta… competitive e…
  - **Enha…**
  - … **and quality** … calibration) of … products by the Copernicus u… unity
  - **R… uce large-scale reprocessing efforts** (because starting from intermediate L1 products rather than from L0)

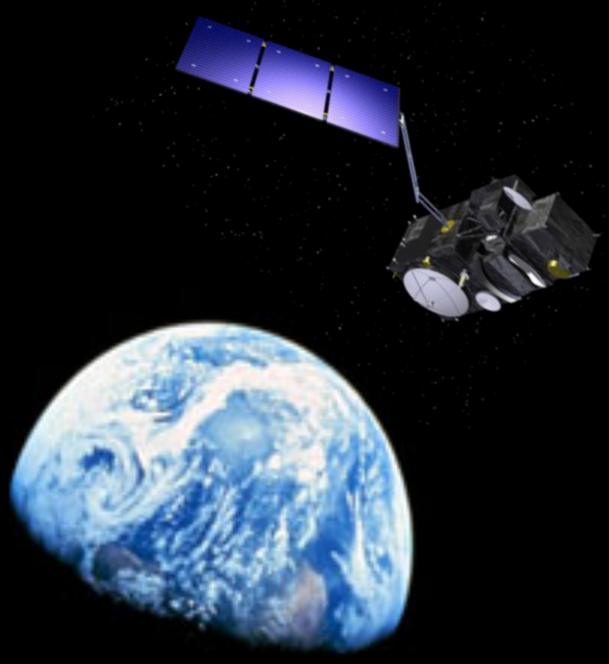


		…for
		…dies …g …eam … …tion studies using ground-based Transponders
	…eo-located, Calibrated gathered azimuth formed complex (I and Q) power echoes after slant/Doppler range correction	Geophysical retrieval algorithm developers (over ocean, land and ice surfaces), surface characterisations studies (e.g. impact of sea state bias, wave directional effects etc) and QC systems
L1B	Geo-located, Calibrated Multi-looked power waveforms	geophysical retrieval algorithm developers and QC systems

Summary

- **ESA Member States have a diverse range of past, present and future satellite missions** that are directly relevant to coastal altimetry
- The role of **Copernicus in the near future will result in an enormous jump in Earth Observation capability**, complemented by the Earth Explorers and Meteorological Missions
- **Altimetry sampling "is what it is": That does not mean that we should ignore the data…we shall use it!**
- **Need to be in Orthometric heights (TG+ALT@coast) – and integrated with Fiducial Reference Measurements (FRM)**
- **This talk did not even consider other complementarity missions that are relevant to water level impacts:** local wind speed and wave measurements, coastal inundation mapping (pre- and post event), hydrodynamic modeling, coastline mapping, storm track and intensity estimation…
- **The challenge is to be ready to fully exploit satellite data and drive the applications forwards…**

This is *exactly* what Sea Level Space Watch is about.



Thank you - any questions?

For more information http://www.esa.int

Contact: craig.donlon@esa.int